VOLUME VIII. NUMBER 3

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

W. F. KING
Chief Astronomer
Ottawa

R. F. STUPART
Director of the Meteorological Service of Canada, Toronto

J. S. PLASKETT
Dominion Observatory
Ottawa

PUBLISHED BI-MONTHLY

MAY-JUNE, 1914

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. VIII. MAY JUNE, 1914 No. 3

On the Structure of the Universe	*J. C. Kapteyn*	145
Location of Epicentres for 1913	*Otto Klotz*	166
Atmospheric Conditions Suitable for the 72-inch Reflector	*W. E. Harper*	172
The 72-inch Reflecting Telescope	*J. S. Plaskett*	180
How Knowledge Grows—I.	*J. C. Glashan*	188
Meetings of the Society		
Meeting of General Council	*J. R. C.*	197
At Toronto	*L. G.*	199
At Ottawa	*R. E. DeL.*	199
At Regina	*A. J. P.*	209
Notes from the Meteorological Service		
Report of the Weather in Canada, April-May	*R. F. S.*	205
Earthquake Records at Toronto and at Victoria, B. C.	*J. V.*	212
Magnetic Observations	*R. F. S.*	214
Astronomical Notes		
Radiation of the Sun		215
The Problems of the Moon's Motion		216
Halley's Comet of 1910		218
Harvard College Observatory		219
The Zeeman and Stark Effects	*J. R. C.*	220
Notes and Queries		
An Extended Meteoric Display in 1783		221
Rotation in a Nebula Detected		223
Is the Centre of the Sun Solid?		224
Earthquake Diagram	*C. A. C.*	227

Editorial communications should be addressed to C. A. Chant, University of Toronto, Toronto, Ont.

Business correspondence, remittances, etc., should be addressed to Chas. P. Sparling, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 35 cents.

Subscription to the *Journal* is included in membership fee.

Anyone wishing to purchase a telescope may correspond with the Secretary, Toronto.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

OFFICERS FOR 1914

Honorary President—W. F. KING, C.M.G., LL.D., Chief Astronomer, Ottawa.
President—J. S. PLASKETT, B.A., D.Sc., Ottawa.
First Vice-President—A. D. WATSON, M.D.
Second Vice-President—A. F. MILLER.
Secretary—J. R. COLLINS. *Treasurer*—CHAS. P. SPARLING.
Recorder—LACHLAN GILCHRIST, M.A., Ph.D. *Librarian*—Dr. W. M. WUNDER.
Curator—ROBERT S. DUNCAN.

Council—The above Officers, and the following members:—H. B. COLLIER, Phm.B., Toronto; Rev. I. J. KAVANAGH, M.A., D.Sc., S.J., Guelph; Rev. Dr. MARSH, F.R.A.S., Peterboro; STUART STRATHY, Toronto; Sir JOSEPH POPE, K.C., M.G., Ottawa; OTTO KLOTZ, LL.D., F.R.A.S. Ottawa; and Past Presidents ANDREW ELVINS, JOHN A. PATERSON, K.C., M.A.; R. F. STUPART, F.R.S.C.; Professor C. A. CHANT, W. BALFOUR MUSSON, Professor A. T. DELURY, Professor LOUIS B. STEWART; and the presiding officer of each Centre as follows: R. M. STEWART, M.A.; T. A. S. HAY, C.E.; WM. BRUCE, J.P.; JAMES DUFF, M.A.; Professor L. A. H. WARREN, M.A., Ph.D., and HENRY WESTOBY, ESQ., F. NAPIER DENISON.

OTTAWA CENTRE

President—R. M. STEWART, M.A. *Vice-President*—F. A. MCDIARMID, B.A.
Secretary—R. E. DELURY. *Treasurer*—D. B. NUGENT.
Council—THOS. FAWCETT, W. E. HARPER, B.A.; R. M. MOTHERWELL.

PETERBOROUGH CENTRE

Local President—T. A. S. HAY, C.E. *Vice-President*—T. C. ELLIOT.
Secretary-Treasurer—T. C. ELLIOT.
Curator—H. O. FISK, C.E. *Librarian*—JOHN H. CRANE.
Council—DUNCAN WALKER, B.A.; S. J. KEYES, B.A.; W. A. LOGAN, C.E.; D. E. EASON, B.A.Sc.; HENRY CARVETH.

HAMILTON CENTRE

Local President—WM. BRUCE, J.P. *1st Vice-President*—W. A. ROBINSON.
2nd Vice-President—REV. J. J. MORTON. *3rd Vice-President*—EDGAR SCHOLES
Secretary—T. H. WINGHAM, B.A. Sc. *Treasurer*—SENECA JONES.
Council—MISS I. M. WALKER, J. F. HARPER, MRS. J. F. HARPER, J. J. EVEL, J. M. WILLIAMS.

REGINA CENTRE

Hon. President—DR. R. A. WILSON, M.A.
Hon. Vice-President—N. MACMURCHY, B.A.
President—JAS. DUFF, M.A. *1st Vice-President*—W. G. SCRIMGEOUR, M.A.
2nd Vice-President—Miss E. D. CATHRO, M.A.
Secretary-Treasurer—ALFRED J. PYKE.
Council—WM. TRANT, P.M.; H. S. MACCLUNG, T. E. MURRAY.

WINNIPEG CENTRE

President—PROFESSOR L. A. H. WARREN, M.A., PH.D.
Vice-President—H. C. HOWARD. *Secretary-Treasurer*—C. E. BASTIN, B.A.
Council—REV. FATHER J. BLAIN, S.J.; PROFESSOR NEIL B. MACLEAN, M.A.; MESSRS. F. POWELL, H. W. MALPASS, J. H. KOLB.

GUELPH CENTRE

Honorary President—COLONEL A. H. MACDONALD, K.C.
Honorary Vice-President—JAS. DAVISON, B.A.
President—HENRY WESTOBY, ESQ.
First Vice-President—PROFESSOR W. H. DAY, B.A.
Second Vice-President—DR. H. G. ROBERTS.
Secretary—PROFESSOR R. R. GRAHAM, B.A., B.S.A.
Treasurer—H. J. B. LEADLAY. *Recorder*—J. S. LUTON, M.A.
Council—J. MCNIECE, B.A.; H. E. S. ASBURY, COLONEL D. MCCREA, F. A. GRAESSER, SHERRIFF A. S. ALLAN, W. LAIDLAW, MRS. J. J. DREW, MISS MARY MILLS.

VICTORIA CENTRE

Honorary President—J. S. PLASKETT, B.A., D.Sc., Ottawa.
President—F. NAPIER DENISON. *Vice-President*—A. W. MCCURDY.
Honorary Secretary—E. H. COTTERELL, C.E.
Executive Committee—W. S. DREWRY, C.E.; W. J. SUTTON, G. G. AITKEN, MAJOR C. B. SIMONDS, C.E.

SAANICH HILL.
Looking East over Elk Lake and Strait.

VIEW FROM PARLIAMENT BUILDINGS, VICTORIA, B.C.

(SITE FOR THE 72-INCH REFLECTING TELESCOPE)

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. VIII. MAY-JUNE, 1914. No. 3

ON THE STRUCTURE OF THE UNIVERSE*

BY J. C. KAPTEYN

THE problem of the present structure of the Universe is the problem of the distances. From the moment that the distances become known we shall be able to make a model which will be a true representation of our stellar system. For, in order to make such a model, we can begin by drawing the lines along which we see the stars. Modern observation determines these directions with considerable precision. All that remains is to locate the stars on these lines and this involves only the knowledge of the distances.

Not only do the distances determine the present arrangement of the stars in space, they also determine the present *change* of the system. For we evidently get the change in direction by observing this direction at two or more different epochs; the change in distance we determine by the well known spectroscopic method of Doppler and Fizeau.

* This paper is reprinted from the international bi-monthly review *Scientia*, for November, 1913. It gives the latest results on a great problem, of whiah its author is considered a foremost investigator.—EDITOR.

During the time that the stars have been observed with something like modern precision we have found the star motions to be practically rectilinear and uniform. If this were rigorously so, and if we were sure that it was so in the past and will continue to be so in the future, then, with the here assumed determination of the distance, we could evidently come to know the past, the present and the future of the arrangement of stars in space. We might then say that we had solved the complete problem of the structure of the universe. But of course our supposition is inadmissible. The mutual attraction of the stars may not make itself much felt in a couple of centuries, but in the course of the ages with which we have to deal in studying cosmical evolution, this attraction must fundamentally change the course of events. The remote past and future of the system, that is to say its *evolution*, must therefore be studied by itself.

Now that I have been asked to write on the subject of the structure of the Universe, I ought to review what has been done of late in regard to the two problems alluded to; but as the subject is too vast for the space at my disposal, I wish to confine myself to that part of it which is concerned with what is called *star-streaming*. I will therefore consider the questions, what has the discovery of star-streaming done, what does it promise to do, for the solution of the two problems: (*a*) The problem of the distances; (*b*) The problem of the history, that is the evolution of the stellar system.

If what has been done as yet seems little, astronomers may plead extenuating circumstances. The time has been over short, — as a consequence we have not yet even approximately the materials we want. If something has been accomplished, we gratefully acknowledge that we owe it largely to American astronomers. Take away the energetic and devoted work done in America and hardly anything would remain of the results I am going to submit here. Little as it is what we know up to the present time, we shall still have to limit the field of discussion. We will, therefore, confine ourselves almost exclusively

to the last of the two problems, devoting but a few sentences to the first.

As to this problem then. It is a well known fact that, with a few exceptions, the star distances are too great for direct measurement. The diameter of the earth's orbit round the sun, which in these measurements is used as a base, has proved to be too small as compared with the stellar distances. In two important cases, where direct measurement seems hopeless or at least very difficult, an indirect method has led to the desired end. I allude to the case of the two physical groups, that of the *Hyades* and that of *Ursa Major*. Both groups show the peculiarity that the stars of which they are composed move with equal velocity in practically parallel lines. For the members of any group in which such is the case we can theoretically work out the distances, by means of observations which nowadays offer no difficulty. Unfortunately in most cases *theoretically* only; for *practically*, as a consequence of the unavoidable errors of observations, we must add the condition that the group must not cover too small a part of the celestial sphere. The method, for instance, fails as yet for the Pleiades, though in this group also, the stars move with equal velocity in parallel lines. The group, however, is too small for a useful application of the method. Let us call this method, — (which for brevity's sake I will not here try to explain), — the method of the Hyades and consider the question:

May not this method of the Hyades be extended to the wholesale determination of the distances in the great stellar system? I think it may to a greater or lesser extent, owing to the discovery of the star-streams.

In order to get a clear idea of what is understood by star-streaming, imagine two clouds of stars. Imagine these clouds to be at first wide apart in space. Let the stars contained in each cloud move, within the cloud, in all directions indiscriminately, much like the molecules of a gas. I shall call this motion the *internal* motion.

Now imagine each cloud to have, in addition, a motion as a

whole, the *cloud or stream-motion*. Furthermore let this motion be such that the clouds are brought together and let us imagine that at the present moment they have penetrated into each other, wholly or partially,—we have no means of judging which. Finally imagine the sun and the solar system somewhere in that part of the clouds where they have thoroughly intermixed and let the sun have a progressive motion of its own.

What a man on the sun, or what is practically the same, on the earth, would see in the supposed case, corresponds closely with what he actually sees happening in the sky.

Had the stars of each cloud no internal motion, that is, were the stars at rest within the clouds, then they would of course have no other motion than that of the clouds themselves and we should see all the stars of the sky moving in two great streams, the members of each stream moving in perfectly parallel lines with what, linearly, must be perfectly equal velocity, the two streams making an angle of about 100 degrees.*

Owing to the internal motions, however, they will not see this. These internal motions will destroy the perfect parallelism and perfect equality, so what really is seen is that the stars move only *preferentially* in two directions making an angle of about 100 degrees with each other. Small deviations from these preferential directions are frequent, greater deviations are much rarer, very great deviations are exceptional.

This describes what is actually observed in the sky. We may say that all the investigations made since the first announcement of star-streaming in 1904, investigations based on very different materials, agree in the establishment of the two preferential directions of motion. We find them in the brighter stars, we find them in the fainter stars; in the swift-moving stars and in the slow-moving stars. They betray their existence in the radial motion as well as in the astronomical motion.

In the *interpretation* of the facts, however, there is a differ-

*Throughout this paper the motions are to be understood as relative to the sun as a fixed point.

ence. *Our* representation by the two independent star-clouds is one of them. Whether this interpretation is the correct one or whether some other interpretation, in which the unity of the system is saved, be the true one, is a question of evolution. We shall have to consider it presently. Our conclusion will then be in favor of the two-cloud theory; and for the sake of greater clearness in the exposition, I shall go on in making use of this representation, though what will be advanced will be in reality not, or but slightly, changed if we start simply from the observed facts.

After this digression let us come back to the question whether the method of the Hyades might not in some way serve for the great system itself. The condition for such an application is that the motions must be equal and parallel.

It must be evident that as long as we consider the system as a whole — and at the time before we knew anything of the star-streams we had no choice but to do so — our condition is not satisfied in the remotest degree. Yet even then the method has proved to be not wholly useless.

But things look altogether different now, at least as soon as we succeed in separating the two streams, that is, in deciding for every individual star to which of the two streams it belongs. At present we are able to do this to a certain extent, but data are fast accumulating which will permit us to do so on a far greater scale in the near future.

This being once accomplished, we can consider each stream separately, and this brings us an enormous step nearer to the Hyades case. We should have the ideal case — more perfect even than it is probably realized in the Hyades — if in each of our own streams what we called the *internal* velocity were *zero*. All the stars would then simply have the cloud or stream-velocity, that is, they would move with the same velocity in perfectly parallel lines. Now this case, it is true, is *not* that of nature. But for *one* great class of stars at least, that of the Helium stars, the internal velocities are very small. The ideal case is therefore satisfied with some approximation. Conse-

quently we can find approximate distances. The approximation even proves to be a pretty good one.

For the other classes the internal motion is more considerable. Still for these too our notions of distance will be very greatly improved as soon as we succeed in separating the members of the two streams.

There is, moreover, a hopeful circumstance. In the closer investigation of the Helium and first type stars we begin to find seemingly clear indications of the fact that our streams are built up of partial streams, which partial streams have slightly, but still distinctly, different motions. In each partial stream the condition of equality and parallelism must be still more nearly satisfied than for the streams as a whole, with the consequence that the distances become even more accurately measurable. There seems to be reasonable hope that further investigation will enable us to trace such partial groups also in the other classes of stars, thereby increasing our power over the problem of the distances for them all.

This very incomplete indication must suffice for the present. It is more than time to proceed to the second of our problems, the main subject on which I wish to offer some remarks, the problem of the history, that is the evolution of the system.

In this study of the history of the system we start from what we know, or think we know, about the evolution of the separate stars.

The stars have been classified by Secchi into *four* types according to their spectrum. We have at present more elaborate classifications, but Secchi's classification, a little modified, will do for the present. Of the stars of the *fourth* type we know as yet so little and their number is as yet so small that we may leave them here out of consideration. Part of the first type has later on been separated from the rest; they show the Helium lines in their spectrum and are now generally placed in a separate class, the class of the Helium stars, already alluded to. We will thus consider the four classes: The Helium stars; the

stars of the 1st, the 2nd, the 3rd type, in which the bulk of all the stars with known spectrum are contained.

Now there is much evidence showing that this classification is a natural one, I mean one of order of evolution, the Helium stars being those of recent birth, while we get to older and older stars in passing from these to the stars of the first, then to those of the second — and finally to those of the third type. I will adopt this view in what follows, though well aware of the fact that some astronomers do not agree with it. I find myself justified in this, not only because I believe this view to be entertained by the great majority of our eminent spectroscopists, but also because it will at once appear that the very phenomena of the star-streams to which I now wish to draw your attention, strongly confirm it.

Where we wish to penetrate into the history of the system it seems natural to treat the problem of star-streaming separately for these four classes of stars. The work offers some difficulties, particularly owing to scantiness of materials. Still, it has been possible to carry it through in such a way as to establish a few facts and to get at least indications about others. We will consider only the two following, about the reality of which there cannot well remain any doubt.

1st. The older the stars, the greater the internal velocity.

2nd. The older the stars, the richer the second stream, at least as compared to the first stream.*

Now these facts at once lead us back to the question just now mentioned, about the order of evolution of the several spectral classes. For this regularity in the increase both of the internal velocity and of the richness of the second stream exists only *if we adopt* for the order of evolution either the order: Helium, first, second, third type or the exact inverse order; third, second, first, Helium, and on no other supposition. Therefore, just with the same right that we expect that all

*It would have been somewhat more correct to say, in regard to this second phenomenon, that there is a regular progression in the order: Helium, 1st, 2nd, 3rd, the types II. and III. not having been as yet separately investigated.

properties of the stars will change with age *gradually* and not *per saltum*, just with that right we judge that the order of evolution must be as we assumed. That the order of evolution is not the reverse (3rd, 2nd, 1st, Helium), is proved by other facts which we cannot now consider. We thus have strong confirmation here of what, on totally different grounds, is pretty generally considered to be the order of the different stages in a star's life.

But to proceed. As the younger the stars are the smaller are their internal motions, it follows at once that from whatever matter our younger stars — the Helium stars — may have been evolved, that matter must in all probability have still smaller internal motion. Let us call this matter *primordial matter*. As the internal velocity of the Helium stars is already so very small we come to the conclusion that primordial matter must practically have hardly any other motion than the motion of the cloud to which it belongs.

There is more. According to the second of the observed facts, the second stream, which is rich in older stars, is much poorer in younger ones. The Helium stars show hardly any trace of a second stream. We must expect, therefore, that for primordial matter there will practically be no second stream or second star cloud. Finally, therefore, we must expect that the particles of primordial matter will all move practically in parallel lines in the direction in which all but a very few of the Helium stars move and with the same velocity.

Now it is a very general notion that it is from the nebulæ that the stars are formed, and from that point of view, what we called primordial matter would be nothing else than the matter of the nebulæ. What precedes gives us the means of testing this notion by observation. What then does observation show?

The number of available data is as yet extremely small. Determination of the astronomical proper motion for the ill-defined nebulæ labors under particular difficulties. Up to the present time it has been invariably unsuccessful.

For the determination of the radial velocity by the spectroscope, the faintness of the nebulæ is a serious obstacle. Owing to this circumstance we know this velocity as yet for no more than 14 nebulæ in all.

Still, even this limited number is decisive in showing that the real motions of these objects are not even approximately parallel to the motion of the Helium stars, or even parallel to any fixed direction whatever. Moreover their velocities are extremely different.

Must we conclude that the nebulæ are *not* the birthplace of the stars? It may seem so. Let us not conclude too hastily however. There are nebulæ and nebulæ. It so happens — and there is ample practical reason for it — that, with one exception, observations of radial velocity have been confined to the so-called planetary nebulæ — very small round or elliptic nebulæ, owing their name to a remote likeness with planetary discs. Herschel saw in them a likeness to what, according to Laplace's cosmogony, must have been the primitive aspect of our solar system and he thus imagined that they must be worlds in *statu nascenti*. According to what we found a moment ago such a view seems now untenable. The planetary nebulæ cannot be the birthplace of the stars. Their motions are such that we must rather assign to them a place at the end of the series of evolution than at the beginning. We may perhaps see an independent confirmation of this view in the phenomena shown by the temporary stars or *novæ*. We must not lose time, however, in discussing this point.

As I just now said, there is one nebula for which the radial velocity has been determined, which is *not* planetary. It is the well known Orion nebula belonging to the class of the irregular nebulæ. May not these irregular nebulæ give birth to the stars?

It turns out that this object has exactly the radial velocity of the first stream Helium stars, that is, we find exactly the motion that we must expect if this nebula is the birthplace of stars. We will not of course, on this single fact, found far-

reaching conclusions. But in my mind we have a right to say that here is a fact singularly strengthening what has already been concluded from other facts, such as the very general connection of the Helium stars with surrounding irregular nebula, etc. We see, moreover, that the observation of the radial velocity of other irregular nebulæ must ere long furnish a crucial test of the theory.

There is another problem involved in our observations, which might seem to be of no less importance than the one just now considered. How have we to explain the fact that the internal velocity of the stars increases steadily as they grow older?

The astronomer who in his study of the motion of the heavenly bodies has found hardly a trace of any other force than gravitation, will naturally turn to gravitation for such an explanation. It really seems a necessity that under the influence of their mutual gravitation bodies, which have little or no relative motion at the outset, must get such a motion, which, up to a certain limit at least, will increase with time. Thus far there is no great difficulty. But now let us look further back in time, back to the time in which the stars had not yet been formed, in which matter was still in its primordial state. If it be true that mutual attraction of the stars has generated such an enormous amount of internal motion in the time needed by the stars for their evolution from Helium to second or third-type stars, how have we to explain the fact that we find that same matter nearly at rest at the first stage of stellar life? That in the pre-Helium ages gravitation has produced hardly any motion? He who believes in a creation of matter at some *finitely* remote epoch may find no difficulty in the question, but to him who does not there is something astonishing to see matter behave as if there were no gravitation. What may be the explanation? Is there really no gravitation in primordial matter? Or is there another force exactly counterbalancing its effects?

I have no solution to offer. I simply wish to point out that

here is a great problem, which, in my opinion, deserves the attention of the physicist no less than that of the astronomer.

I now wish to draw your attention to the question alluded to before: Does the observed fact of the preference in the star-motions for *two* definite directions, lead us necessarily to the assumption that our universe has been evolved by the meeting of two independent star-clouds, or is it still possible — and in that case more natural — to explain it without sacrificing the unity of the system?*

Suppose a very elongated star-cloud, in which the stars are originally at rest. Let this cloud be left to the mutual attraction of the bodies of which it is composed. Those in opposite parts of the cloud will begin to fall towards each other. Two streams will be set up, opposite in direction, approximately parallel to the axis of the cloud, though in no wise absolutely or exclusively so. In other words we get two preferential directions of motion. There is no real difficulty in the fact that they are exactly opposite, whereas the streams observed in the sky make an angle of about a hundred degrees. For opposite streams, viewed from a self-moving body as in our earth, will appear to make an angle and we can readily determine the motion of the earth in such a way as to bring us into harmony with observation. Thus far no objection. But there are further consequences. In an elongated universe as is here assumed, both the mean longitudinal velocity — which in this article was called the stream-velocity — and the deviations therefrom — the internal motion — will gradually increase, beginning with velocity *zero*.

Now for the internal velocities we found such an increase. Do we find the same for the stream-velocity?

By no means.

Recent Mount Wilson observations have enabled us to derive at least a pretty reliable value of the stream velocities for the first-type stars. For the Helium stars we can as yet only

* The following considerations are borrowed from a lecture held at Harlem in 1906 (Programme de la Soc. Holl. des Sciences pour 1906, p. LIV.).

assign a limit which the relative velocity of the two streams must exceed. For the older stars we have had a reliable value for some time. All these determinations show that, contrary to what takes place with the internal motions, the relative velocity of the two streams must be roughly the same for the older and younger stars, and cannot differ much even in the case of the Helium stars.

It seems to me that this fact is fatal to the present explanation.

Schwarzschild has developed a different theory which also leaves the universe a unit, but this theory too, elegant though it be, cannot, I think, be maintained. Among other things we have, as a main objection, the second of the observed facts treated in what precedes — a fact which was not yet known when Schwarzschild brought his theory forward. In his theory the assumption is involved that the number of stars in the two streams is equal. This may be not too far from the truth for the second and third type stars, but for the first type the number of stars in the second stream cannot be much different from *one-third* of that in the first stream. For the Helium stars it is not a *tenth*. The second stream is so poor here that it has been altogether overlooked till quite recently.

The conclusion to be drawn from all this seems obvious. It would seem that we are driven to the theory, assumed in this article from the first, the theory of the two star-clouds, which, owing to their initial velocity, have come to meet and intermingle. It must be confessed, however, that in this theory too there remain some hard nuts to crack. Until we succeed in this operation it seems unsafe to claim any great certainty for the theory, and it seems preferable to put it forward as the hypothesis which, for the time being, best fits the observed facts.

There remains to be considered the question how to explain that the second stream or cloud hardly contains any Helium stars.

There is something in the smaller star-groups which may help us. Everybody knows the group of the Pleiades. There

can be no doubt but that the bright and many of the faint stars that we see in this part of the sky, are really near together in space and not merely near together in the same visual line, the one far behind the other. They form a physical system and must have a common origin. At present we know several such groups: among them the already mentioned Hyades and Ursa Major group, and we may perhaps count among them the great Scorpius-Centaur group.

Now in these local groups we find, as a first remarkable fact, that, ignoring a few though significant exceptions, if we arrange the members in the order of their absolute brightness, we at the same time find them approximately arranged in the order of the spectra. As an instance, take the Scorpius-Centaur group. We find the very brightest stars to be of the very earliest Helium type; the somewhat fainter ones are older Helium stars, the much fainter ones are of the first type. If we cannot follow the series further on to the second and perhaps the third type, this seems to be only the consequence of our lack of knowledge of the fainter stars belonging to the group. In the Pleiades, where observation extends somewhat further, we can at least follow the series down to the middle of the second type. It follows from this that in all these groups what there is of Helium stars cannot escape our notice, for they are all bright and our knowledge of the bright stars is sufficiently complete.

Notwithstanding this — and this is the second remarkable fact, the fact that bears directly on the question in hand — we find not a single Helium star either in the Hyades or in the Ursa Major group. The stars in these groups show the same change of spectrum with the brightness, but instead of beginning with the earliest Helium stars, the series begin abruptly with the second stage of star-life.

In the Pleiades the series begins somewhat earlier; still here even there is not a single star of the earliest Helium type. There is an abrupt beginning with the medium Helium stars.

It is only in the Scorpius-Centaur group that we find the complete series.*

Our second stream, therefore, behaves much as do the local groups of the Hyades and Ursa Major. The explanation must in all likelihood be the same in both cases.

How therefore, does it come to pass that in such groups as those of the Hyades and Ursa Major, the Helium stars are absolutely wanting?

For those adopting the view, as I did in this article, that the series Helium, 1st, 2nd, 3rd type is a series of evolution, there is little doubt but that there has been a time when the stars, now of the 1st type, were Helium stars. Therefore the groups that do not now contain any Helium stars must have contained them formerly in great numbers. Going back in time still further, these Helium stars must have been generated from some other matter, probably nebulous matter. Therefore in a remote past the groups of the Hyades and Ursa Major must have been full of nebula. As far as I know, there is no trace of nebulosity now. So there must have been an epoch in the past that nebulous matter was exhausted, had probably all gone to the formations of stars. Since that epoch, evidently, no more Helium stars could be evolved, and as the Helium stars already formed gradually transformed into first-type stars, we see the necessity of a time in which the group must not contain any more Helium stars. Therefore, finally, our answer to the question: how does it come to pass that in the second stream or cloud we do find hardly any Helium stars? would be: because since some time nebulous matter must have been exhausted in this cloud. As to the first stream or cloud we must similarly conclude: nebulous matter must not yet have been exhausted, or if so, only in very recent time.

It has been my aim, to show *not* that much has been done, but that there is a beginning; *not* that we have entered far into the promised land, the land lying open to the human view so

*I think that in the two phenomena here alluded to we may see further evidence of the order of evolution Helium, 1st, 2nd, type.

temptingly since the first man looked up to the sky, but that a few pathways are being mapped out, along which we may direct a hopeful attack. Our problems take a more definite form and though we were never to solve them completely let us remember the word of the poet:—"If God held in his right hand all truth and in his left nothing but the ever ardent desire for truth, even with the condition that I should err forever, and bade me choose, I would bow down to his left, saying, 'O, Father, give; pure truth can be but for thee alone.'"

UNIVERSITY,
GRONINGEN, HOLLAND.

LOCATION OF EPICENTRES FOR 1913

By Otto Klotz

IN the following, which is in continuation of similar series published for 1911 and for 1912, we deal only with earthquakes that have been recorded at Ottawa, but not necessarily all the phases of each quake; so that, as will be found in the table, many earthquakes are located without the requisite data from Ottawa, as is the case when possibly only S and L or L alone are recognizable on the seismogram. The plotting, as heretofore, has been done on our printed forms and using the "Stereographic Projection Tables" published by me in January, 1912.

In the accompanying table, column 1 gives the dates of the quakes whose locations were attempted with the data at hand. When two quakes fall upon the same day they have been differentiated by giving the nearest hour (G.M.T.) of the beginning of the disturbance. Columns 2 and 5 give all the data available, the distance being in kilometres, and taken directly, when given, from the various bulletins, or deduced from the P and S times. Column 2, however, gives only those stations for which the intersections are satisfactory, and of such intersections the centre of gravity is taken for the epicentre, the co-ordinates of which are then found in column 3. The remaining data, unsatisfactory or conflicting with those of column 2 are entered in column 5 as "other data." When all the data give unsatisfactory intersections then in column 2 is put "no location," and the stations used as "data" in column 5. In column 4 are given the co-ordinates as determined at other stations. What was designated in 1911 and 1912 as "Galitzin" is now replaced by "Pulkowa." The Russian "first-class" stations determine the epicentre on the data of one station (its own) alone. The co-ordinates given

by Cartuja are taken from *Ciel et Terre*, No. 2, 1914. Last year our list contained 47 quakes, this year we have 54. As we confine ourselves to quakes of which some record is obtained at Ottawa, as well as at some other stations, European and more particularly Asiatic stations would, following the same scheme, have more quakes to examine and plot, than we have here. The number of cases in which "no location" occurs is attributable to various reasons. Foremost amongst them is the discordance in distances given, and this is mostly due, I think, to inaccurate interpretation of the seismogram, and not to any conspicuous short-coming of the Wiechert-Zöppritz time-curve, or values for $S - P$. Again, there may be only a few stations available, and if one or the other gives a wrong distance, the necessary satisfactory intersection is not obtained. And again, if all the first class stations would make their data more rapidly available, the "no locations" would undoubtedly be reduced in number. In some cases we have very satisfactory agreement of the position of the epicentre, determined from different stations, and from different sets of stations. This would show that the above time-curve is, say up to 10,000 km., fairly accurate. However, taking the results for the year, we must admit that they are far from satisfactory, although great strides have been made in the last few years. Without wishing to be invidious, one can not help noting the splendid bulletins that are being issued by the Imperial Russian Earthquake Commission for their "first-class" stations. The epicentre given by Tiflis for August 13 is evidently quite erroneous, placing it in the Atlantic south of Newfoundland and east of Cape Hatteras, when in reality it lies within the Java Sea. However the error is undoubtedly due to a misinterpretation of the vertical component, reading a push for a pull or vice versa.

I assume that accurate time, which was not had at many stations a few years ago, is now universal at the important stations and reliable to within a second, made so where not otherwise provided by the availability of the wireless signals, from the Eiffel and Norddeich stations in Europe, and from the

Arlington station in America. The question of accurate time which heretofore was a disturbing factor in earthquake investigation and location of epicentres, should no longer give serious concern. An earthquake station without accurate time is now an inexcusable condition. To repeat, the inaccuracies which we encounter in attempting to locate an epicentre are primarily due to incorrect distances obtained from faulty interpretation of the seismogram, that is, in recognizing *P* and *S*, leaving *L* out of consideration altogether.

I do not think that there is uniformity in reading either *P* or *S*, even when they are well-marked, *i. e.*, just at what point *P* or *S* begins, so as to fit in with the Wiechert-Zöppritz time-curve. Strictly speaking it would fall on Professor Wiechert to supply this information by means of seismograms indicating the above points exactly. However such information comes quite properly within the functions of the International Seismological Bureau. And it is suggested that a number of well-recorded earthquakes by different types of seismographs be reproduced or manifolded (natural size) and a set sent to every seismological station, properly marked and showing the various phases. A proceeding like this would help to standardize readings which at present does not obtain. We cannot hope to correlate properly unless we have uniformity of methods and proceedure. Probably in none of the other sciences is co-operation so imperative as in seismology, the science of most recent birth, and we must look to the Central Bureau in furthering and bringing about systematic co-operation, whereby we may eventually unravel the mysteries of the interior of the earth.

The stereographic plotting has been done by R. C. McCully of our office.

Location of Epicentres for 1913

Note.—The figures following a station in the 2nd and 5th columns refer to the distance in kilometres from the respective station to the epicentre.

Date	Stations	Epicentre		Remarks
1913			Pulkowa	Other data:
Jan. 11	Batavia = 1800	$\varphi = 0°{\cdot}5$ N.	$\varphi = 6°{\cdot}0$ N.	Manila = 3250,
	Irkutsk = 5950			Pulkowa = 9250,
	Tiflis = 8850	$\lambda = 121°{\cdot}6$E.	$\lambda = 117°$ E.	Zi-Ka-wei = 3150
Jan. 15	No Location			Data:
				Aachen = 9100,
				Graz = 9800,
				Harvard = 3700,
				Irkutsk = 8600,
				Ottawa = 3800,
				Pulkowa = 9750.
Jan. 19	Aachen = 9100	$\varphi = 5°{\cdot}6$ N.	Cartuja	Other data:
	Cartuja = 9750	$\lambda = 84°{\cdot}2$ E.	$\varphi = 1°{\cdot}6$ N.	Athens = 6450,
	Pulkowa = 8000		$\lambda = 89°{\cdot}5$ E.	Graz = 8400,
			Pulkowa	Hamburg = 8800,
			$\varphi = 4°{\cdot}7$ N.	Tashkend = 5700,
			$\lambda = 91°{\cdot}7$ E.	Zi-Ka-wei = 4750.
			Tashkend	
			$\varphi = 3°{\cdot}2$ N.	
			$\lambda = 85°{\cdot}9$ E.	
Jan. 20	Graz = 8600		Cartuja	Aachen = 8000 and
	Hamburg = 8100		$\varphi = 47°{\cdot}8$ N.	Cartuja = 9500
	Irkutsk = 3350	$\varphi = 46°{\cdot}7$ N.	$\lambda = 152°{\cdot}7$ E.	fall short of the ad-
	Makejevka = 7500	$\lambda = 149°{\cdot}4$ E.	Irkutsk	joining epicentre.
	Pulkowa = 6950		$\varphi = 49°{\cdot}5$ N.	
	Strassburg = 8800		$\lambda = 152°{\cdot}9$ E	
	Tiflis = 7700		Pulkowa	
	Zi-Ka-wei = 2950		$\varphi = 49°{\cdot}1$ N.	
			$\lambda = 155°{\cdot}3$ E.	
Feb. 7	Irkutsk = 5650		Irkutsk	
	Pulkowa = 9700	$\varphi = 3°{\cdot}1$ N.	$\varphi = 15°{\cdot}5$ N.	
	Zi-Ka-wei = 3100	$\lambda = 120°{\cdot}5$ E.	$\lambda = 148°{\cdot}8$ E.	
Feb. 20	Aachen = 8800		Cartuja	Hamburg = 8300,
	Graz = 8800		$\varphi = 44°{\cdot}4$ N.	Irkutsk = 2900, and
	Pulkowa = 7050	$\varphi = 42°{\cdot}0$ N.	$\lambda = 141°{\cdot}3$ E.	Tiflis = 7450 came
	Strassburg = 8950	$\lambda = 141°{\cdot}6$ E.	Irkutsk	near to adjoining epi-
	Tashkend = 5800		$\varphi = 42°{\cdot}4$ N.	centre.
	Zi-Ka-wei = 2150		$\lambda = 140°{\cdot}7$ E.	
			Pulkowa	
			$\varphi = 43°{\cdot}9$ N.	
			$\lambda = 144°{\cdot}9$ E.	
			Tiflis	
			$\varphi = 48°{\cdot}5$ N	
			$\lambda = 147°{\cdot}3$ E.	

LOCATION OF EPICENTRES FOR 1913

Date	Stations	Epicentre		Remarks
Mar. 6 (11h).			Cartuja φ = 34°·0 N. λ = 86°·0 E.	Vienna = 10300 discordant.
	Graz = 5900 Irkutsk = 2900 Manila = 4200	φ = 31°·2 N. λ = 84°·0 E.	Irkutsk φ = 36°·6 N. λ = 74°·7 E. Pulkowa φ = 32°·0 N. λ = 84°·0 E.	
Mar. 8	No Location			Data : Cartuja = 8700, Harvard = 3450, Ottawa = 1350, St. Louis = 3800.
Mar. 14	No Location		Irkutsk φ = 5°·6 N. λ = 126°·3 E. Pulkowa φ = 15° N. λ = 129° E. φ = 11° N. λ = 123°·5 E.	Data : Aachen = 9600, Cartuja = 11000, Graz = 10300, Irkutsk = 5550, Pulkowa = 9050, Pulkowa = 9150, St. Louis = 8800, Strassburg = 10150, Tiflis = 8800, Vienna = 9700, Zi-Ka-wei = 2800.
Mar. 23	Irkutsk = 4350 Pulkowa = 8700 Tashkend = 6850 Zi-Ka-wei = 2200	φ = 25°·6 N. λ = 143°·1 E.	Cartuja φ = 32°·2 N. λ = 141°·4 E Irkutsk φ = 25°·4 N. λ = 142°·2 E. Pulkowa φ = 26°·3 N. λ = 143°·3 E. Tiflis φ = 31°·7 N. λ = 148°·3 E.	Manila = 2450, Tiflis = 8700, agree fairly well with adjoining epicentre. Other data : Batavia = 4700, Graz = 9000, Vienna = 9150.
Mar. 31	(i) Ottawa = 7250 St. Louis = 6800 Vienna = 9400 Zi-Ka-wei = 5450 (ii) Irkutsk = 5250 Ottawa = 7250 St. Louis = 6800 Tiflis = 9200	φ = 46°·0 N. λ = 177°·0 W. φ = 47°·5 N. λ = 178°·7 W.	Irkutsk φ = 54°·6 N. λ = 167°·4W. Pulkowa φ = 52°·0 N λ = 50°·3 N. φ = 180°·2 E. λ = 177°·9 E. Tiflis φ = 43°·3 N. λ = 172° E.	Other data : Cartuja = 9400, Graz = 9000, Hamburg = 8550, Harvard = 7850, Manila = 3050, Pulkowa = 7300, Pulkowa = 7450, Strassburg = 9100.

Location of Epicentres for 1913

Date	Stations	Epicentre		Remarks
April 13	Irkutsk = 3300 Tiflis = 7350 Vienna = 9100	$\Phi = 27°{\cdot}3$ N. $\lambda = 126°{\cdot}2$ E.	Irkutsk $\Phi = 32°{\cdot}2$ N. $\lambda = 134°{\cdot}6$ E.	Other data : Graz = 9000, Hamburg = 8900, Pulkowa = 7600.
April 18	Batavia = 2700 Pulkowa = 9300 Tashkend = 6500 Tiflis = 8500 Zi-Ka-wei = 2500	$\Phi = 9°{\cdot}2$ N. $\lambda = 121°{\cdot}3$ E.	Irkutsk $\Phi = 13°{\cdot}3$ N. $\lambda = 129°{\cdot}7$ E. Pulkowa $\Phi = 13°{\cdot}5$ N. $\lambda = 130°{\cdot}6$ E.	Irkutsk = 4900 falls short of adjoining epicentre.
April 24	Irkutsk = 4900 Pulkowa = 9250 Tiflis = 8650	$\Phi = 13°{\cdot}2$ N. $\lambda = 129°{\cdot}7$ E.	Irkutsk $\Phi = 12°{\cdot}5$ N. $\lambda = 128°{\cdot}0$ E. Pulkowa $\Phi = 13°$ N. $\lambda = 128°$ E.	Other data : Graz = 9500, Vienna = 9900, Zi-Ka-wei = 2500. Irkutsk gives a second distance 6575, and $\Phi = 2°{\cdot}0$ S., $\lambda = 132°{\cdot}2$ E.
April 25 (18h).	Hamburg = 9450 Tashkend = 6800 Vienna = 9700 Zi-Ka-wei = 2500	$\Phi = 33°{\cdot}8$ N. $\lambda = 148°{\cdot}3$ E.	Pulkowa $\Phi = 15°{\cdot}7$ N. $\lambda = 134°{\cdot}6$ E. also $\Phi = 11°{\cdot}3$ N. $\lambda = 125°{\cdot}3$ E.	Other data : Batavia = 3000, Graz = 9500, Göttingen = 9600, Irkutsk = 5250 Pulkowa = 9280, Pulkowa = 9200, Tiflis = 8800.
April 26	No Location			Data : Ottawa = 3600, Pulkowa = 9000, St. Louis = 3250.
April 29	Graz = 9000 Irkutsk = 4550 Tiflis = 8550	$\Phi = 49°{\cdot}9$ N. $\lambda = 172°{\cdot}2$ E.	Cartuja $\Phi = 50°{\cdot}4$ N. $\lambda = 170°{\cdot}7$ W.	
April 30	Ottawa = 6650 Tiflis = 8850 Zi-Ka-wei = 5650	$\Phi = 52°{\cdot}2$ N. $\lambda = 174°{\cdot}2$W.	Irkutsk $\Phi = 53°{\cdot}7$ N. $\lambda = 166°{\cdot}1$ W. Pulkowa $\Phi = 50°{\cdot}2$ $\lambda = 176°{\cdot}3$	Göttingen = 8500, Vienna = 8550, come fairly close to adjoining epicentre. Other data : Graz = 9500, Irkutsk = 5600.

LOCATION OF EPICENTRES FOR 1913

Date	Stations	Epicentre		Remarks
May 8	No Location		Pulkowa $\phi = 6^{\circ}$ S. $\lambda = 179^{\circ}$ E.	Data : Harvard = 6000, Irkutsk = 3550, Ottawa = 5100, Pulkowa = 13500.
May 16	No Location			Data : Irkutsk = 4700, Ottawa = 5350, Pulkowa = 7300.
May 30	No Location		Irkutsk $\phi = 1^{\circ}{\cdot}0$ N. $\lambda = 159^{\circ}{\cdot}6$ E. Pulkowa $\phi = 6^{\circ}$ S. $\lambda = 154^{\circ}$ E.	Data : Graz = 11200, Irkutsk = 7800, Pulkowa = 12400, Strassburg = 7500, Vienna = 11300, Zi-Ka-wei = 4000.
June 4	No Location		Irkutsk $\phi = 1^{\circ}{\cdot}1$ S. $\lambda = 148^{\circ}{\cdot}8$ E. Pulkowa $\phi = 17^{\circ}$ N. $\lambda = 144^{\circ}$ E.	Data : Batavia = 1250, Cartuja = 12900, Graz = 8350, Irkutsk = 7200, Manila = 2300, Pulkowa = 9650, Tashkend = 9000, Tiflis = 9650, Zi-Ka-wei = 4200.
June 14 (9h).	Cartuja = 9250 Hamburg = 9400 Ottawa = 3750	$\phi = 15^{\circ}$ N. $\lambda = 93^{\circ}{\cdot}7$ W.	Cartuja $\phi = 20^{\circ}$ N. $\lambda = 99^{\circ}$ W. Pulkowa $\phi = 25^{\circ}{\cdot}7$ N. $\lambda = 99^{\circ}{\cdot}8$ W.	Other data : Graz = 9000, Harvard = 3600, La Paz = 2700, Makejevka = 9650, Pulkowa = 9500, Strassburg = 9200, Vienna = 9500.
June 14 (10 h).	Cartuja = 2650 Graz = 1000 Hamburg = 1650 Ottawa = 7550 Pulkowa = 1850 Zi-Ka-wei = 8000	$\phi = 43^{\circ}{\cdot}3$ N. $\lambda = 26^{\circ}{\cdot}9$ E.	Cartuja $\phi = 43^{\circ}{\cdot}3$ N. $\lambda = 27^{\circ}{\cdot}0$ E. Pulkowa $\phi = 43^{\circ}{\cdot}5$ N. $\lambda = 25^{\circ}{\cdot}9$ E.	Other data : Aachen = 1700, Göttingen = 1550, Harvard = 7650, Irkutsk = 5500, Strassburg = 2200, Tiflis = 1600, Vienna = 1150.
June 14 (12 h).	i)Cartuja = 2650 Pulkowa = 3500 Strassburg = 2500	$\phi = 53^{\circ}{\cdot}2$ N. $\lambda = 28^{\circ}{\cdot}3$ W.		Other data : Göttingen = 2750, Hamburg = 2900, Harvard = 3250, Tiflis = 5750.

Location of Epicentres for 1913

Date	Stations	Epicentres		Remarks
June 14 (12h).	(ii) Aachen — 2750 Ottawa = 3100 Pulkowa = 3500	$\phi = 59°{\cdot}8$ N. $\lambda = 35°{\cdot}2$ W.		
June 22	Aachen = 8700 Hamburg = 8350 Ottawa = 7000 Pulkowa = 7450	$\phi = 50°{\cdot}8$ N. $\lambda = 178°{\cdot}9$ W.	Cartuja $\phi = 52°$ N. $\lambda = 178°{\cdot}2$ W. Graz $\phi = 52°{\cdot}5$ N. $\lambda = 164°{\cdot}5$ W. Hamburg $\phi = 51°$ N. $\lambda = 170°$ W. Pulkowa $\phi = 50°{\cdot}8$ N. $\lambda = 178°{\cdot}6$ W.	Graz = 8950, Strassburg = 9000, agree fairly well with adjoining epicentre. Other data: Cartuja = 10000, Harvard = 7700, St. Louis = 6500, Vienna = 8700.
June 26	No Location		Apia $\phi = 15°{\cdot}0$ S. $\lambda = 173°$ W. Irkutsk $\phi = 10°{\cdot}6$ S. $\lambda = 177°{\cdot}9$ E. Pulkowa $\phi = 23°$ S. $\lambda = 186°$ E. Riverview $\phi = 19°{\cdot}5$ S. $\lambda = 176°$ W.	Data: Irkutsk = 9850, Manila = 2900, St. Louis = 4900, Zi-Ka-wei = 9000.
July 7	No Location		Irkutsk $\phi = 13°{\cdot}0$ S. $\lambda = 132°{\cdot}2$ E. Pulkowa $\phi = 9°{\cdot}6$ S. $\lambda = 153°{\cdot}4$ E.	Data: Graz = 6950, Irkutsk = 7750, Manila = 3400, Pulkowa = 12750, Strassburg = 7500, Tashkend = 9600, Vienna = 11000, Zi-Ka-wei = 4000.
July 8	(i) Batavia = 5000 Manila = 2650 Makejevka = 6100	$\phi = 37°{\cdot}6$ N. $\lambda = 114°{\cdot}6$ E.	Irkutsk $\phi = 4°{\cdot}8$ S. $\lambda = 142°{\cdot}2$ E.	Other data: Graz = 9400, Irkutsk = 7800, Pulkowa = 13000, Tashkend = 9600, Zi-Ka-wei = 4000.
	(ii) Batavia = 5000 Manila = 2650 Samoa = 4200	$\phi = 17°$ N. $\lambda = 145°{\cdot}6$ E.		

LOCATION OF EPICENTRES FOR 1913

Date	Stations	Epicentre		Remarks
July 12	Pulkowa = 8600 Tiflis = 8700 Zi-Ka-wei = 2200	ϕ = 27°·3 N. λ = 143°·7 E.	Irkutsk ϕ = 29°·9 N. λ = 143°·4 E. Pulkowa ϕ = 27°·9 N. λ = 144°·4 E.	Other data : Batavia = 5150, Cartuja = 10750, Irkutsk = 4150, Manila = 2550, Ottawa = 3300, Vienna = 9600.
July 22	No Location		Irkutsk ϕ = 3°·8 S. λ = 147°·1 E. Pulkowa ϕ = 5° S. λ = 155° E.	Data : Graz = 6900, Irkutsk = 7450, Pulkowa = 12350, Tashkend = 9250, Tiflis = 9550.
July 25	No Location		Pulkowa ϕ = 16°·0 N. λ = 78° W.	Data : Graz = 9500, Makejevka = 10650, Ottawa = 3600, Pulkowa = 9450.
July 26	Harvard = 4150 Pulkowa = 2500 Strassburg = 2500 Vienna = 2800	ϕ = 66°·1 N. λ = 18°·1 W.	Pulkowa ϕ = 67°·5 N. λ = 18°·6 W.	Ottawa = 4000, Aachen = 2350, agree fairly well with adjoining epicentre. Other data : Irkutsk = 5350.
July 28	No Location			Data : Cartuja = 9500, Harvard = 6450, Ottawa = 6800.
Aug. 1	Aachen = 8800 Hamburg = 8400 Ottawa = 8350 Pulkowa = 7100 Strassburg = 8950 Vienna = 8750	ϕ = 47°·6 N. λ = 159°·4 E.	Irkutsk ϕ = 50°·5 N. λ = 155°·3 E. Pulkowa ϕ = 47°·3 N. λ = 155°·0 E. Cartuja ϕ = 45°·3 N. λ = 145°·4 E.	Other data : Cartuja = 10100, Harvard = 8100, Irkutsk = 3450, Tashkend = 6500.
Aug. 5	Graz = 8900 Irkutsk = 6000 Pulkowa = 7500 Tashkend = 8550	ϕ = 52°·3 N. λ = 159°·8 W.	Irkutsk ϕ = 56°·1 N. λ = 153°·4 W.	Other data : Makejevka = 6600.

Location of Epicentres for 1913

Date	Stations	Epicentre		Remarks
Aug. 6	Cartuja = 9350 Harvard = 6500 La Paz = 620 Ottawa = 6850	ϕ = 16°·1 S. λ = 73 ·5 W.	Cartuja ϕ = 14°·4 S. λ = 74°·4 W. Pulkowa ϕ = 11°·9 S. λ = 74°·4 W.	Other data : Aachen = 10000, Graz = 10000, Pulkowa = 11950, Strassburg = 9850, Vienna = 9300.
Aug. 7	No Location			Data : Graz = 9700, Ottawa = 6850, Pulkowa = 11950,
Aug. 13	Irkutsk = 6100 Makejevka = 8850 Pulkowa = 9600 Tashkend = 6350 Tiflis = 8150 Zi-Ka-wei = 4000	ϕ = 2°·9 S. λ = 109°·1 E.	Irkutsk ϕ = 2°·1 S. λ = 109°·3 E. Pulkowa ϕ = 2°·9 S. λ = 108°·1 E. Tiflis ϕ = 35°·0 N. λ = 54°·1 W.	Other data : Graz = 9000.
Aug. 15	Irkutsk = 4250 Pulkowa = 8550 Tashkend = 6750 Zi-Ka-wei = 2100	ϕ = 26°·7 N. λ = 142°·6 E.	Irkutsk ϕ = 28°·0 N. λ = 143°·9 E. Pulkowa ϕ = 26°·9 N. λ = 141° E.	Other data : Graz = 9500, Vienna = 9200.
Aug. 31	No Location			Data : Pulkowa = 11250, Tashkend = 9250, Zi- Ka-wei = 4350.
Sept. 3	Batavia = 5100 Tashkend = 9700 Zi Ka-wei = 5050	ϕ = 2°·8 S. λ = 153°·0 E.	Irkutsk ϕ = 6°·5 S. λ = 150°·3 E. Pulkowa ϕ = 7°·5 S. λ = 150°·8 E. Tashkend ϕ = 5°·0 S. λ = 151°·6 E. Tiflis ϕ = 13°·7 S. λ = 141°·6 E.	Other data : Cartuja = 9500, Graz = 9000, Hamburg = 9750, Irkutsk = 7850, Pulkowa = 12400, Ottawa = 6100, Tiflis = 11600.
Oct. 2	Cartuja = 8400 Gottingen = 9400 Hamburg = 9300 La Paz = 2900	ϕ = 6°·4 N. λ = 80°·7 W.	Pulkowa ϕ = 9° N. λ = 78° W.	Other data : Aachen = 9000, Harvard = 4000, Irkutsk = 6350,

LOCATION OF EPICENTRES FOR 1913

Date	Stations	Epicentre		Remarks
Oct 2	Ottawa = 4400			Pulkowa = 10150, St. Louis = 3100, Vienna = 9400, Reported near Panama.
Oct 4	Cartuja = 8350 Göttingen = 9400 La Paz = 3000 Ottawa = 4150	ϕ = 8°·1 N. λ = 81°·4 W.		Other data : Graz = 9400, Pulkowa = 9250.
Oct 11 (2h).	No Location		Irkutsk ϕ = 6°·0 S. λ = 147°·7 E. Pulkowa ϕ = 6°·2 S. λ = 150°·5 E.	Data : Aachen = 8700, Batavia = 4850, Graz = 8900, Irkutsk = 7650, Ottawa = 4250, Pulkowa = 12250, Tashkend = 9400.
Oct. 11 (4h).	No Location		Irkutsk ϕ = 6°·0 S. λ = 148°·5 E. Pulkowa ϕ = 6°·7 S. λ = 150° E.	Data : Aachen = 8750, Batavia = 4450, Cartuja = 9150, Göttingen = 8600, Hamburg = 8650 Irkutsk = 7700, Ottawa = 11500, Pulkowa = 12250, Tashkend = 10400, Zi-Ka-wei = 4950.
Oct. 11 (9h).	Aachen = 9100 Göttingen = 8900 Hamburg = 8650 Irkutsk = 3400 Pulkowa = 7400 Zi-Ka-wei = 2250	ϕ = 39°·5 N. λ = 144°·3 E.	Irkutsk ϕ = 38°·2 N. λ = 143°·7 N. Pulkowa ϕ = 39°·7 N. λ = 143°·9 E.	Batavia = 6250, Tashkend = 6050, agree fairly well with the adjoining epi- centre. Other data : Graz = 9000, Vienna = 9000, Ottawa = 9700.
Oct. 14	No Location			Data : Irkutsk = 9100, Ottawa = 9600, Zi-Ka wei = 7400.
Oct. 23	Cartuja = 8350 Ottawa = 4150 Pulkowa = 10300	ϕ = 8°·9 N. λ = 81°·4 W.		

Location of Epicentres for 1913

Date	Stations	Epicentre		Remarks
Nov. 15	No Location		Irkutsk $\phi = 20°{\cdot}6$ N. $\lambda = 145°{\cdot}8$ E. Pulkowa $\phi = 21°$ N. $\lambda = 146°{\cdot}9$ E.	Data : Batavia = 6800, Irkutsk = 5000, Makejevka = 9600.
Nov. 19	Batavia = 2000 Irkutsk = 6250 Tashkend = 7250	$\phi = 1°{\cdot}3$ S. $\lambda = 124°{\cdot}1$ E.		Other data : Manila = 1700, Pulkowa = 8300,
Nov. 23	No Location		Tiflis $\phi = 50°{\cdot}5$ N. $\lambda = 157°{\cdot}9$ E.	Data : Irkutsk = 4050, Pulkowa = 8150, Tiflis = 7900.
Dec. 21	No Location			Data : Graz = 8000, Pulkowa = 6700, Tashkend = 3500, Tiflis = 5700.
Dec. 25	No Location		Pulkowa $\phi = 35°$ N. $\lambda = 37°$ W.	Data : Graz = 4200, Irkutsk = 9500, Pulkowa = 5400.

Dominion Observatory,
Ottawa, Canada,
May, 1914.

ATMOSPHERIC CONDITIONS SUITABLE FOR THE 72-INCH REFLECTOR

By W. E. Harper

THE proposal to instal a powerful reflector necessitated an investigation to see where it could be most effectively used. It is the aim of this article to describe in a brief and popular way something of the work done during the past year by the writer in connection with this investigation.

In choosing an observatory site some of the more important factors to be borne in mind may be enumerated as follows. For a large reflecting telescope they are arranged probably in ascending order of importance.

(1) Hindrances of a general nature, such as high winds, dust, dews, fogs, earthquakes, etc., etc.

(2) The proportion of clear sky or the number of nights that will be available each year for work.

(3) The transparency of the sky.

(4) The range in temperature, particularly the range during the working hours of the night.

(5) The quality of the "seeing," *i. e.*, the steadiness, definition, etc., of the star images.

These are the most important considerations from an astronomical point of view. Then there are material considerations such as the accessibility of the site, its suitability for buildings, the availibility of electric power, etc., which must be given due consideration.

The sites of most observatories have not been chosen with regard to astronomical suitability. Usually there are limitations which render this impossible. The observatory has to be a part of a university equipment, perhaps, and as such is limited to a

region accessible to the university. The Yerkes Observatory, in connection with the University of Chicago, may be instanced; though it must not be inferred that this site is unsuitable for an observatory. The site of the great Lick telescope seems to have been selected by its donor and improvements begun before any astronomical tests were carried out, though later observations by Professor Burnham and the work done at the observatory have shown it to be exceptionally good. The observatory near Santiago, Chile, the southern dependency of the Lick Institution, was placed where the climatic conditions, as given in the weather reports, were adjudged most hopeful. Quite extensive tests were carried out by Professor Hussey, acting for the committee in charge, when Mt. Wilson was selected as the site of the Solar Observatory. He spent some three months in the summer of 1903 making tests upon various suggested mountains in Southern California.

It seemed natural that the Meteorological Reports which give the general climatic conditions such as temperature, precipitation, character of the days, etc., would be of first importance in selecting in a general way where favorable locations might be looked for. Thanks are due the Director of the Meteorological Service, Mr. R. F. Stupart, who made valuable suggestions in this connection. The table compiled of places all over Canada showed that the following seemed to be most favorable :—Ottawa, Gravenhurst, Winnipeg, Battleford, Medicine Hat, Calgary, Banff, Okanagan Valley, Kamloops and Victoria. In the matter of clear sky Gravenhurst, Calgary and Battleford led slightly but there was not a great deal to choose between any of them. Victoria was the lowest, but this was more than offset by its remarkably low range in temperature, about one-half of that at the other places.

Keeping in mind that preference be given to stations of southerly latitude, so that more stars in the Southern Hemisphere could be reached, these places were simmered down to four which were thought to be representative of the various regions. The prairie section should produce uniform atmospheric condi-

tions, particularly if an elevated plateau were available, and of such places Medicine Hat was deemed the most promising. The Rocky Mountain section when high altitudes are possible was deemed worth testing and Banff was selected as the typical spot. The dry belts of British Columbia were considered promising also and the Okanagan Valley, Penticton district, was selected, while Victoria with its exceedingly small diurnal range of temperature gave promise of steady conditions, and it made up the fourth place outside of Ottawa where specific tests were to be carried out. Incidentally during the progress of the work a cursory examination of a number of other places was made.

The principal instrument used was a four-and-a-half-inch telescope, equatorially mounted. The objective is the well-known Cooke Photo-Visual and the telescope is equipped with eye-pieces ranging in power from 60 to 320. The highest power was used where ever feasible so as to make as severe a test of the seeing as possible. A camera for plates of cabinet size was also attachable. The photographic work was intended merely to serve as a check upon the visual, upon which almost entire dependence was to be placed. Lists of close double stars from Burnham's catalogue and of a number of faint stars at about the limit for the telescope were made up and examination was to be made of these at the various selected places. The limiting separation for double stars is for this telescope about one second of arc, *i. e.*, the distance that must exist between two stars so that one could tell that the star was double would be of that magnitude. Owing to unsteady seeing conditions and consequent diffuseness of the images it is only rarely that any telescope will resolve down to its theoretical limit. Thus the better the seeing the smaller the star images will be and the closer can we approach to the limiting power of the telescope. For this reason the examination of close double stars with a view to learning the separation that could be detected formed the bulk of the observational work. Then too, the character of the diffraction pattern would tell something of the steadiness: while the transparency could be arrived at from unaided eye observations of objects at

about the limit in brightness for the eye, and also, in a measure, from the ease with which faint objects could be picked up in the telescope, though caution would have to be exercised in this latter procedure as it is hard to dissociate transparency from steadiness.

Besides the telescope, a few other instruments, an anemometer, a hygrometer, a thermograph, etc.,—instruments of a meteorological nature—were taken along.

After some preliminary work in May and early June in Ottawa I left Ottawa June 12th to examine more specifically the seeing at these selected places. They were visited both going and returning so that different seasons of the year might be experienced; Medicine Hat the latter half of June, Banff the fore part of July, Penticton the latter half of July, Victoria the month of August, save for a short visit to the Lick Observatory to compare with conditions there; on the return, Penticton the first three weeks of September, Medicine Hat the latter part of September and part of October. On my return to Ottawa October 12th, I worked some three weeks making similar tests here as had also been done in the spring.

It would be outside the scope of this paper to enter into a detailed description of the "seeing" experienced at the various places. A number was assigned to each night which would represent the conditions found. The number 5 was taken as a maximum which would represent perfect conditions, something unattainable in practice. The numbers 4, 3, 2 and 1 would represent lessened values of the seeing conditions. Where the work is done by one observer uniformity is secured and reliable comparisons can be made.

Considerable broken weather was experienced during the first stay at Medicine Hat but the seeing was better than expected in such weather and gave promise of better things in a clear spell. At Banff normal weather prevailed but the steadiness was so poor—the images always being in a state of "flux"—that it was eliminated at this stage. Clear weather prevailed during my first stay at Penticton—it was hot, too—and much better

seeing conditions were experienced. At Victoria, both sessions, the seeing was of a high standard of excellence the images on many nights reminding one of a "steel engraving" effect, so beautiful and steady was the diffraction pattern. Returning to Penticton in September some broken weather was experienced, but about ten nights were available before leaving, two of which almost came up to Victoria's standard in the matter of steadiness. At Medicine Hat some beautiful autumn weather was experienced, hardly a cloud being seen the first seven or eight days. It was expected the seeing would be correspondingly good but, whatever the cause, it was very poor.

The transparency at Medicine Hat (altitude 2300 ft.), Banff (4800 ft.), Penticton (altitudes 1700 ft. and 2800 ft.) appeared to be about the same and exceeded Victoria (230 ft.) and Ottawa (270 ft.) by about 20 per cent.

In the matter of range of night temperature — from sunset to sunrise, clear nights only considered — and quality of seeing itself, the two most important items in the case before us we have for the summer tests:

Place	Range of Night Temperature	Seeing on a Scale of 5
Medicine Hat	7·5°C	2·3
Banff	9·2	1·3
Penticton	7·2	3·1
Victoria	3·8	3·8
Ottawa	7·6	2·6

Clearly Medicine Hat and Banff were at once out of consideration and Penticton's superiority of transparency and proportion of clear sky was more than offset by Victoria's small range in night temperature and high value of the seeing conditions. If removal from Ottawa were to be considered Victoria should be the favored spot.

Owing to the limited time spent at Victoria and especially as my visit was made in August which might prove to be one of the best months in the year for "seeing", the Director, Dr. W.

F. King, felt that further work should be done before anything final was settled. Consequently I returned to Victoria about the end of November to examine conditions during the worst weather and incidently take stock of suitable locations should the matter be decided in favor of Victoria.

This is the season of cloudy skies, and during my stay of nearly a month I made observations on only fourteen nights and of these only six would be classed as really workable. The seeing conditions on these nights, however, were very little below the summer standard, being rated 3·3 as compared with 3·8 for the summer. One night, that of December 17th, may be mentioned to bring out a certain characteristic. It was uncertain up to the last moment whether it would be clear or not and under such unsettled conditions one is not disappointed if good seeing is not experienced for some little time. However things seemed to settle rapidly into their stride and the night was good right from the start. Star images were down to their theoretical diameters and doubles of 1″·0 separation could easily be measured.

Returning to Ottawa, December 30th, I worked till the middle of January making similar tests and the following table will sum up both summer and winter conditions.

	Wind	Clear Sky	Transparency	Night Temperature Range	"Seeing"
Ottawa	Same, 7 or 8 miles per hour.	Practically same, 42 per cent.	What difference there is will be in favor of Victoria	7°·6 C	Victoria 50 per cent. better than Ottawa.
Victoria				3·8	

Thus it resolves itself into a comparison of the last two factors in both of which Victoria is markedly superior to Ottawa. While I had discussed with the Lick and Yerkes astronomers the relative weights that should be given each factor no definite numerical values were arrived at. These were obtained by Dr. Plaskett after my results had been tabulated and are discussed in his article.

During my last visit to Victoria in December occasion was

taken to look over possible locations. It had been in my mind that possibly somewhere in the highland district where reasonable altitudes could be had would be best, but upon further study I felt that the precipitation and consequent cloudiness would be against that district. A few miles there, seems to make considerable difference in regard to these. At Victoria the total yearly precipitation is about 26 inches; some ten miles to west or northwest it is considerably more than double that amount. It was finally narrowed down to the immediate vicinity of Victoria and the Saanich Peninsula which enjoys a climate somewhat like the city itself. The elevations in close, are mostly to the north-east of the city where they would be affected by the city's smoke driven by the prevailing south-west winds. Mt. Douglas, 725 feet, some five miles out in a park reserve of some 350 acres was considered; Mt. Newton, 1000 feet, some fourteen miles north also offered some advantages, being extensively wooded, but Little Saanich, 732 feet, seven and a half miles from Victoria, being close to the main road between Victoria and Sidney and similarly close to the electric line seemed to possess advantages outweighing the others.

A word may be added regarding my visit to Lick Observatory on Mt. Hamilton, California. It was deemed expedient to make some comparisons with this place which is considered to be one of the best sites on the continent for night seeing at least. I left Victoria August 13th and proceeded to Mt. Hamilton, remaining there four days and nights. Just here I wish to bear testimony to the hospitality I enjoyed there. The acting Director, Mr. R. H. Tucker, and in fact every member of the staff did everything to make my visit most pleasant and profitable. With Dr. Aitken in charge I was permitted to examine the seeing with the 36-inch telescope, the 12-inch quite freely and a 6-inch finder also. Although unusually poor seeing conditions obtained while I was there, yet from our estimates I feel that our conceptions of what constitutes perfect seeing are about the same. That being the case I feel that, except in two particulars, we will enjoy at Victoria seeing equal to that of Mt. Hamilton.

Those two particulars are the number of nights workable — we will not have so many — and the transparency. I am bound to admit that the transparency of the atmosphere at the Lick Observatory is superior to that of any place I examined in Canada. But in the matter of low temperature range and the character of the seeing itself I think we may look for conditions to equal those upon Mt. Hamilton.

It gives me pleasure to acknowledge the helpful advice of Dr. J. S. Plaskett and the Director, Dr. W. F. King, in the carrying out of this work.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
May, 1914.

THE 72-INCH REFLECTING TELESCOPE

By J. S. Plaskett

AN account of the history of the project and a short description of the proposed design for the telescope was given by the writer in the November-December number of this Journal. Since that date further developments have occurred which the Editor has asked me to record.

The most important, of course, is the question of the location of the instrument. As indicated in the article referred to, the question has been under consideration for some time and astronomical and other observations have been made at several places in Canada by Mr. Harper for the purpose of testing the "seeing" and other conditions. The methods employed and the results obtained are fully detailed by him on another page of this issue.

It will suffice to say that the comparative tests made at Medicine Hat, Banff, Penticton, Victoria and Ottawa showed such marked superiority of Victoria over all the other places that only it and Ottawa need be considered as sites for the telescope.

It need hardly be said that very great astronomical advantages must be shown to justify the additional expense and complication entailed by establishing a separate observatory away from Ottawa. Besides the problems of organization and management of a branch institution, considerably greater construction expenditure will be involved. If located at Ottawa, the dome and necessary substructure would be all that would be required in the way of buildings. But, if located away from Ottawa, an office building with library, etc., of considerable size, residences for the director and four astronomers, water, electric power and drainage systems, to say nothing of land

costs and roads would be required. The whole makes a formidable additional outlay, and removal will only be justified if great astronomical advantages will accrue.

A reference to the data compiled by Mr. Harper shows that in the transparency of the atmosphere, and the quantity of clear sky there is little to choose between Victoria and Ottawa. But when we come to "seeing" or steadiness and quality of definition, Victoria excels Ottawa by 50 per cent. (as 3·8 is to 2·6 on scale of 5), and in low range of night temperature as 3° 8 is to 7°·6 C.

In order to determine to what extent these differences would affect the quantity and quality of the work produced by a large reflecting telescope, enquiries were sent to the directors of the Lick, Mt. Wilson and Yerkes Observatories for their opinions as to the relative value of the two locations.

From their replies it was estimated :—

1. That two and a half times the quantity of spectrographic work can be done at Victoria.

2. That work of much better quality is possible at Victoria.

3. That much high class work, impossible under the unfavorable atmospheric conditions at Ottawa, could be successfully undertaken at Victoria.

Such a difference in the quantity of the work is equivalent to saying that stars a magnitude fainter, twice as many in number can be reached, a very important increase in the range and usefulness of the telescope. This may be otherwise expressed. The 72-inch telescope at Victoria could do as much work and of better quality than one of 114 inches aperture at Ottawa. As the cost of large telescopes varies approximately as the cube of the aperture, the larger instrument even if possible of construction, would cost four times as much ; in comparison with which the additional outlay for installation at Victoria is insignificant.

An equally favorable financial comparison is obtained when the cost of upkeep is balanced against the quantities of work at

the two places. Any given quantity of work will cost nearly twice as much at Ottawa as at Victoria.

In view of the advantages to Victoria and the Province of British Columbia of the establishment of an observatory with a telescope larger than any in use, it was thought advisable by Dr. King and the writer to see if the Government of British Columbia would give some assistance. It was considered that they might reasonably be asked to help in the matter of land for the site and of a road to the observatory which should be situated at some elevation probably at present inaccessible.

The writer hence visited Victoria in February last and interviewed the Premier and Members of the Government, asking them to provide the necessary land and to build a road to the site which had provisionally been chosen on Saanich Hill, elevation 732 feet, about 8 miles north of Victoria. He was sympathetically received and his proposals were considered in a most liberal and broadminded way by the Government. They agreed to provide $10,000 for the purchase of land and to build a road to the summit of the hill, an action which will be highly commended by every man of science, and is undoubtedly strongly approved by the residents of Victoria and vicinity and by the province generally. I am glad to express here my appreciation of their progressive policy and also to render my thanks to those in Victoria who by their influence helped the matter along and also made me so much at home among them.

A full statement of the relative values of Victoria and Ottawa from an astronomical standpoint and of the financial and other aspects of the question, closing with a strong recommendation that the telescope be placed near Victoria was then submitted to the Government by Dr. King.

The Hon. Dr. Roche who has throughout been most sympathetic towards the project, strongly backed up this recommendation, and the Government decided in favor of Victoria.

Every man of science, not only in Canada, but in the whole civilized world will applaud the policy of the Government in this

matter. They have dealt with the question in the most broad-minded and progressive way. Their action in sanctioning the construction of this telescope, larger than any in use, has now been rendered doubly effective in the cause of science by placing it, independently of any local or sectional influences, where the best and most work can be done. The whole forms one of the largest, if not the largest, single contribution to science ever made by any country, and Canadians should be proud that their country has so splendidly furthered the cause of astronomical research.

Immediately after the decision of the Government and before its announcement the writer was entrusted with the purchase of land for the site, and again proceeded to Victoria early in April. During his previous visit in February and March the district had been carefully examined, observations of the "seeing" and daily temperature gradient taken, and as previously stated a hill about eight miles north of the city had been selected as the most suitable. A summary of the reason for the choice is desirable.

The observations of Mr. Harper were made in Victoria West at an elevation of about 200 ft. Obviously such a site would not do for the observatory which must be away from city lights and smoke, and yet near enough to be accessible. The region around the city which has the low precipitation and unique climatic conditions of Victoria is quite limited in area, and is practically confined to the eastern section of the Saanich Peninsula, the south eastern extremity of Vancouver Island extending north about twenty miles and having an average width of about five miles. This peninsula is composed of rich alluvial soil with a number of isolated rocky hills, "monadnocks," rising from it.

All conditions pointed, therefore, to a choice of one of these elevations as a site for the new observatory. There are four hills over 700 feet in the peninsula: Mt. Newton, 1000 ft., 15 miles from the city; Bear Hill, 718 ft,, 10 miles; Saanich Hill, 732 ft., 8 miles; Mt. Douglas, 725 ft., 5 miles. At the westerly

part of the peninsula are ranges of hills culminating in Mt. Wark, 1445 ft. But as the precipitation is greater here and they are difficult of access they were not considered. The choice becomes narrowed down to three, as Mt. Douglas is not only rather close but is in the direction of the prevailing winds and subject, therefore, possibly to city smoke.

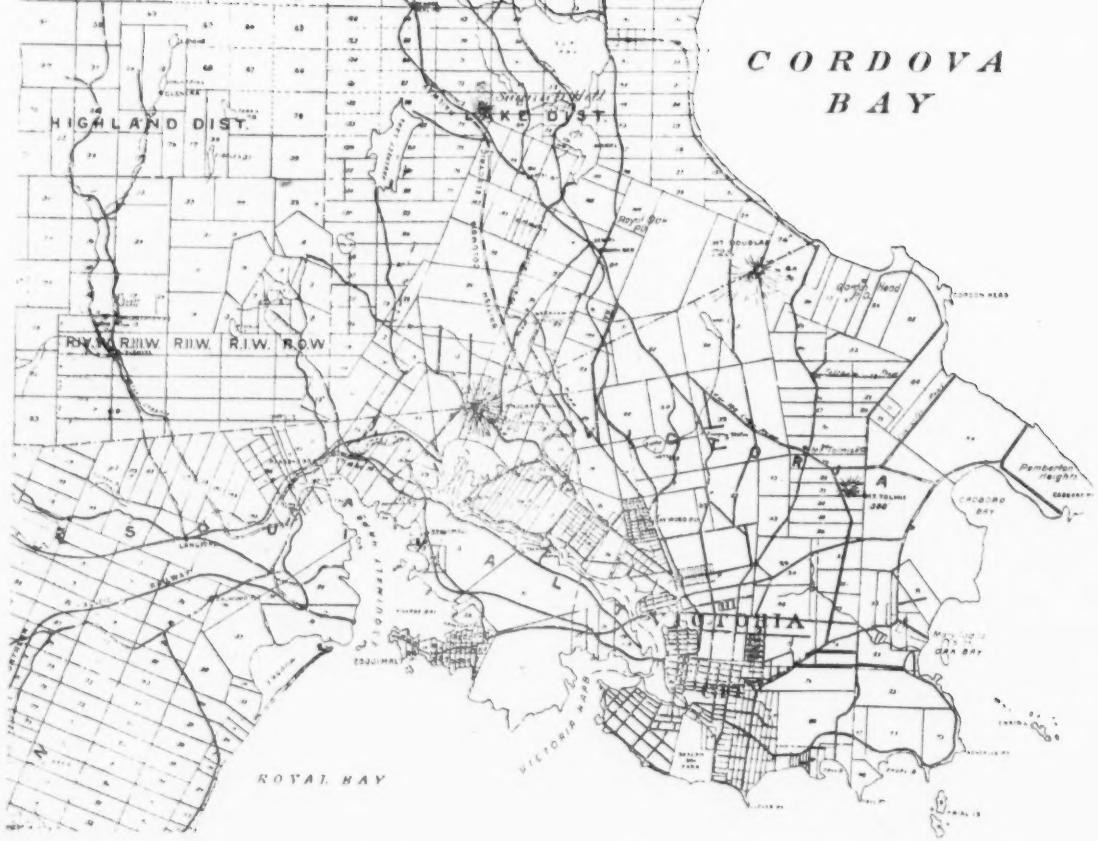
Saanich Hill, locally known as Little Saanich, is the most accessible, as the West Saanich Road and the B. C. Electric Railway pass close to the foot of the hill, while distant two or three miles from Bear Hill and Mt. Newton. Similarly the cost for an electric power line to the summit will be much less with Saanich Hill. There is probably little to choose astronomically between them, for though Mt. Newton is higher, it rises from higher surrounding area and the air drainage and consequently seeing and temperature conditions will be so little superior to Saanich Hill as to be insignificant compared with its greater distance and inaccessibility.

Comparative tests of the "seeing" at the summit and foot of Saanich Hill and at Victoria were carried out by the writer with a portable telescope during parts of March, April and May. it was found that the "seeing" was always better at the summit than at the lower levels. This difference was more marked when the seeing at the foot of the hill or at Victoria was poor. For example when it was 2·0 to 2·5 at the lower altitudes it was 3·0 to 3·5 on the summit. When it was good, 4·0 say, below, it was about three points better or 4·3 on the summit. It is evident then that the "seeing" will be considerably superior on the hill to that found by Mr. Harper during his visits to Victoria.

Furthermore, the night range of temperature on the hill is also considerabiy lower than at Victoria and the fall is more gradual and uniform. The average fall of temperature during observing hours, over the short period in which observations were taken, was about 3° C.

It is, of course, true that the interval over which the observations, on which the location has been decided, is not very long

SAANICH INLET
BAZAN BAY
COLE BAY
GORDOVA CHANNEL
JAMES ISLAND
SIDNEY CHANNEL
SIDNEY ISLAND
SOUTH SAANICH
IIW IW I.F IIE IIE IVE VE VIE
DARCY I.
CORDOVA



SCALE TWO MILES TO ONE INCH.

MAP OF PART OF SAANICH PENINSULA

Showing Victoria, and the Hills to the north. Saanich Hill is almost in the centre of the map.

and that it would be desirable to have them extend over a period of years. However, all the observations at Victoria taken during the three seasons of summer, winter and spring have shown such a marked superiority over conditions at Ottawa as to leave no reasonable doubt that the choice is amply justified. Furthermore an immediate decision of the latitude of the observatory was necessary for the construction of the mounting and it was not possible, as it has not generally been possible in similar cases, to continue the observations further before choice was made. These remarks apply, of course, only to the "seeing." Other conditions of cloudiness, wind velocity and especially the important one of daily temperature variation, are reliably known from the meteorological data extending over many years, and show that in low temperature gradient, Victoria is easily superior to any place in Canada and has only half the range of Ottawa.

After considerable difficulty fifty acres of land surrounding the summit of Saanich Hill were secured. A greater area to prevent possible industrial or other encroachments would have been desirable but this was prevented by the high price at which property is held all over the peninsula. However, there is ample land for the buildings and the property extends on the east, west and south of the summit well down over the slopes so that we are well protected in the directions in which the great majority of the observations will be carried on.

The map shows the location of the hill in the peninsula with respect to Victoria and to the roads and electric railway, and the photograph taken from the first floor of the Parliament Buildings shows how prominent a feature of the landscape, the hill surmounted by a 66-foot dome will be, as seen from most parts of Victoria. The summit and upper levels of the hill are very attractive with magnificent views in all directions.

The other photographs show that they are pleasantly wooded and of a park-like character. Very little work will be required when the buildings, which should so far as possible be designed and placed, to harmonize with the surroundings,

are completed, to make the grounds into a beautiful natural park. Easy access to these grounds and the observatory will be given by the Provincial Government road to the summit, which will be located so as to take advantage of the scenic points in the climb to the top. The whole will form a great attraction, not only for astronomers but also for visitors and residents of the vicinity.

The road is to be built this season, and it is proposed to start the construction of the dome and building for the telescope first thing next spring. Word has been received from Paris that the disc for the mirror is ready for shipment and there is every prospect of the telescope being ready for erection next year.

On my return from Victoria a visit was paid to the Warner and Swasey Co. Very satisfactory progress is being made with the design of the mounting which is constantly being improved and perfected in details. The design of the large and important parts such as the tube, polar axis and bearings is completed, and the construction of the heavy steel castings and forgings required, about to commence. The design of the electric quick and slow motions and the necessary clamps and clutches, is now occupying their attention, and very complete and perfect arrangements for the operation of the massive moving parts, about forty tons in weight, are well under way.

A great deal of attention has been given and time and labor expended by the Warner and Swasey Co. in computing stresses and deflections, in designing and modifying the design to give the best possible results. I can only say that I am in the highest degree delighted with their work and firmly convinced that this telescope in rigidity, suitability and convenience will be away ahead of any hitherto built.

I cannot close this paper without expressing in some slight degree my appreciation of and gratitude to Dr. King for the way in which he has endorsed and carried out my plans in regard to the telescope. Especially is it necessary to bear

SAANICH HILL
Looking S. W. from 620 ft. elevation.

SAANICH HILL
Looking N. W. towards Summit from 640 ft. elevation.

tribute to his action in regard to the location of the instrument. It is natural to expect that he would wish to keep such a magnificent instrument in Ottawa under his direct supervision and as part of the splendid institution he has built up. But the work was paramount with him, and the final decision to place the telescope in the best place astronomically was based on and largely influenced by his strong recommendation in favor of Victoria.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
June, 1914.

HOW KNOWLEDGE GROWS — I.

By J. C. Glashan

THERE is an old proverb, "Curiosity is the beginning of knowledge." Of curiosity itself the exciting cause is novelty and the starting point is astonishment. The transition from "This is novel; this is strange" to "I do not understand it," and from the latter to, "What is it?" would seem to be instinctive: hence the immediate effect of meeting with the unknown or the unfamiliar, when fear does not intervene, is an increase of mental activity resulting in an overflow of nervous energy which, if uncontrolled by the intellect, impels to that emotional curiosity so strongly exhibited by children and many of the lower animals, but which, if controlled and guided by the understanding, arouses the rational curiosity which has given us all science, all our knowledge of the laws of nature, which has enabled us

> "To scatter the mists that enclose us,
> Till the seas are ours and the lands;
> Till the quivering æther knows us,
> And carries our quick commands;
> From the blaze of the sun's bright glory
> To sift each ray of light;
> To steal from the stars their story
> Across the dark spaces of night."

Emotional or irrational curiosity is marked in the child by persistent and insistent questioning as aimless as the dance of gnats in the evening sunshine, as impulsive as the frolics of kittens at play, and as inconsequential as the gambols of a puppy around its mother. Rational or scientific curiosity is distinguished by sustained and persevering investigation as purposeful as the search of the honey-bee for honey and pollen, as patient as the cat watching at a mouse-hole, and as unswerving in aim as the famished grey wolf tracking its quarry

> "With long hard gallop which can tire
> The hound's deep hate and hunter's fire."

The query of emotional curiosity is *Why? Why? Why?* with an occasional *What?* or *Where?* Too often the only possible answer to the "Why?" is "I don't know;" to the "What?" a mere name. In truth, the child's question "What is that?" often means no more than "What is its name?", just as with some persons of a larger growth, "Who is that?" means in many cases nothing more than "What is his name?" The demands of rational curiosity are *What?*, *Where?*, *When?* and *How?*, the last being distinctively *the* scientific question. But if the curiosity halts at the bare item of information given by the answer to the query *What?* or *How?* it is no more truly rational than is that of a child. Some people have the same propensity to collect a jumble of unconnected scraps of information as the school-boy has to collect all sorts of odds and ends in his pockets. There are men who, if you were to mention Jacob's ladder to them, would ask how many rungs it had. The curiosity which is truly rational, the curiosity which has led to science, does not stop at mere observation of the strange object, the new fact, or the novel experience; it does not rest satisfied with the mere acquisition of new information, but seeks to discern the precise difference between the new experience and former experiences, and endeavors to assimilate the new knowledge with the knowledge already possessed, bringing both underone principle, one law, which broadens with the unifying process and opens up far-stretching vistas to the eye of the intellect.

I have used the words, *knowledge*, *science*, *law*, but as these have, in common speech, a multiplicity of meanings, many of them differing widely from each other and by this discordance too often leading, in discussions, to misunderstanding and confusion, you have a right to demand that before I go any further I shall delimit and declare the meanings in which I shall use these terms.

Knowledge, which in its origin and form has no parallel in English speech, has had three main meanings, but two only of

these are now in use, and with these two alone are we concerned. These meanings are however, so distinct that in all the languages of Europe other than English, they are expressed by separate words, words that are even non-cognate. *To know* may mean to perceive, to apprehend, to be or become conscious of by the senses, or it may mean to understand, to comprehend, to grasp mentally. For example, the blind astronomer Sanderson could not know in the former meaning, perceive, the apparent motions of the heavenly bodies, but he knew in the latter meaning, understood, their relative motions well. *Knowledge* then means both the perception of a person or a thing or the apprehension of a fact or a truth as identical with or as distinct from one perceived or apprehended before, and also the intellectual comprehension or understanding of a fact or a truth with clearness and a feeling of certainty.

Science in general is the whole body of man's knowledge set in organic order ; it is, therefore, a systematised and co-ordinated statement of the results of the investigation of phenomena and of the laws of phenomenal reality. Each special science will, therefore, be a collection of the general principles and leading truths of some particular branch of knowledge, clearly enunciated and systematically arranged so as to be easily remembered, referred to and applied. The general principles and leading truths which thus form the content of science are usually spoken of as *natural laws*, but the term *law* used here is apt to be misleading on account of its very different signification in the phrases, *the moral law*, *the civil law*, *international law*, *an unjust law*. A natural law is a mere record of experience upon which we base our interpretations of that which does happen and our anticipations of that which will happen, or briefly, a natural law means an invariable, unconditional relation either of succession or of co-existence. Perhaps the simplest examples of natural law which I can give you are the three laws known as Kepler's.

If these delimitations and definitions are accepted, an immediate consequence is that the growth of knowledge, the

advance of science, begins with observation, immediate or recorded, continues with the analysis of observations and the discovery and formulation of natural laws, and culminates in the application of these laws to exploring for new facts, unveiling new truths and detecting still wider laws, themselves in turn to yield to wider still.

Observation constitutes the foundation of all knowledge, but the base-layer, the broad ground-layer is personal experience and instant inference therefrom. John Bunyan has likened the soul of man to a city set upon a hill and fenced about with a high wall which none may overleap and none may undermine, but through which pierce five gateways by means of which alone all communication with the outer world is held. He names these, Eye Gate, Ear Gate, Mouth Gate, Nose Gate and Feel Gate. (It was an Irishman who declared that there are seven senses, seeing, hearing, tasting, smelling, feeling, common sense and nonsense, and it was a Scotchman who daringly said "These seven are but six, — the two last are one.")

Bunyan restricted his simile to the soul of man, but it equally applies to at least all the higher warm-blooded animals. "Children and fools learn by experience," but so also do horses, cows, cats and dogs. If "the brunt bairn dreeds the fire," so too, "the scalded dog flees cold water." The teaching of experience applies to man and beast alike, but to man with his possession of speech and especially to civilized man with his invention of writing and reading comes the mightier power of each making his own the experience of all, untrammelled by the shackles of space and time. Each beast observes, and must observe, for himself, he knows by experience only, but every man observes for all men and all observe for each; and if some observations are discoloured or distorted in the making or in the transmission, this can generally be remedied before they are made final records in the book of Knowledge.

Observations are necessary, observations are, and must be, made, but all men do not observe alike. One man sees a thousand things where another sees but one. How is this? Let

a proverb, "one man's wit and all men's wisdom," answer; — "The eye sees what it brings the power to see."

> "Pussy cat, Pussy cat, where have you been?
> I've been in London to see the Queen.
> Pussy cat, Pussy cat, what saw you there?
> I saw a little mouse under her chair."

The cat saw the mouse because it had an inherited power to see and an inherited food-interest in mice. In the struggle for existence, the cats which did not see mice quickly went under, while those who saw quickly and acted instantly, survived and left offspring with like powers of vision and action.

For thousands of years before Archimedes was born, men must have seen the water in a water-hole or a bath-tub rise as their bodies sank into it, and Archimedes himself must often have unheedingly observed the same thing, but when he was brooding over the problem of how to find the volume of the metal-work in the royal crown, without injury to the delicate workmanship, his mind was turned to measurements, and his eye was ready, — had the power, — to see measurements in all things. So when he entered his bath and saw the water rise as he lowered himself into it, and sink as he rose out of it, the solution of his problem flashed to his mind, and leaping from his bath, he rushed home through the streets of Syracuse clad as Adam when in his innocence, and pealing forth in triumph εὕρηκα! εὕρηκα! I have found (it)! I have found (it)!

Two thousand years after the royal crown had been successfully measured, a favourite challenge question of the Irish philomaths was, — How can you find the solid contents of a bundle of thorns?

A nursery rhyme and a story! But why not? Are not nursery rhymes "The wisdom of our fathers on the lips of our children," even as the games of boys are far off echoes of the hunt and the foray of their savage ancestors, and the games of girls dim reminiscences of courtship and motherhood of matriarchal times? As for the story, — it is possibly true, but is probably a fable. If it is not true, 'tis pity 'tis not true, for it

simply and surely teaches that it is not the eye that observes but the mind behind it, that not alone must there be power to see, there must also be preparedness, and yet more, to power of sight there must be added that "gift of the gods," power of insight.

But the spirit of man does not rest satisfied with the observation of facts or phenomena; having seen and heard he must explain. To the questions *What?* *Where?* *When?* succeed the questions *How?* and *Why?* Thus knowledge grows.

From the earliest times, man has felt an impulse, a desire, to explain the *why* and the *wherefore* of the outside world; and the explanations which have been offered are many, but when examined they all fall into one or other of three classes, the anthropomorphic, the occult, and the mechanical; the two first attempting to answer the question, *Why?*; the last seeking to answer the question *How?*

When primitive man attempted to solve "the riddle of the universe," when the child of to-day attempts the same task, his most unquestionable bodily experience was and is that emotion and willing are absolutely necessary antecedents of all motion. A chemist has said, — "without phosphorus, no thought;" the primitive man and the child believe, — "without emotion, no motion," and hence peering out between the gate-bars of the senses, they postulate the same sequence, feeling, willing, acting, for all visible movements and changes in the outer world. Now while this explanation may do very well when applied to fellow-men, to beasts and to birds, when it comes to the movements and interactions of sticks and stones, of winds and waves, of forest and stream, of sun, moon and stars it necessitates giving to each a spirit of its own, a spirit that is soon endowed with all the passions, all the powers of feeling of his creator, in short a spirit made in the image of man.

To follow up these crude beginnings of the anthropomorphic explanation to their higher and subtler forms would require more time than is at my disposal, even had I the ability and the knowledge; suffice to say it was the earliest, it is the oldest,

solution of the enigma of nature that man has given. It is the explanation that is accepted by the vast majority of mankind to-day; it is the answer that we all learned in our childhood, and which, for many happenings, we will carry to our graves. It is the explanation that still sways, in great part, our thoughts and our conduct, and that has dominated religion and at times has even usurped its place. It is the answer that led to the belief that the black death and the plague were punishments for spiritual sins and that, till the discoveries of Pasteur and the researches of his followers, accounted a visitation of typhoid ferve a punishment for moral turpitude, not for civic filth.

The second class of explanations of the world of phenomena ascribed to all bodies specific qualities which as separate entities were not apprehensible by the senses or comprehensible by the intellect, — were occult, — but on which depend, in some unknown manner, the properties, operations and interactions of the bodies. Sugar is sweet because it possesses the specific property of saccharinity, and glue sticks things together because there inheres in it the specific quality of adhesiveness. It was an explanation that offered words for thoughts, mere tokens for minted coins. It was a learned way of speaking that cloaked ignorance. It was the explanation of the pretended disciples of Aristotle, pseudo-peripatetics; it became the explanation of the quack and the montebank, it is to-day a jargon on their lips. We need not farther dwell on it.

When and where men first became dissatisfied with anthropomorphic explanations of natural phenomena, history does not record, but it does record that suddenly among those wonderful people we call the ancient Greeks, thinking men, weary of guessing her riddles, turned to study Nature herself, and began to ask *how* she acted, not *why* she acted so. The growth of knowledge was now rapid, "there were giants in the earth in those days." The earth was found to be a sphere and its size was determined with wonderful nearness to accuracy, the distance of the moon was also roughly measured and an attempt was made to determine the distance of the sun. The movements

of the planets were observed and an attempt was made to represent them by uniform motion in excentric circles and in epicycles carried on uniformly rotating concentric circles. This doctrine of epicycles and excentrics, crystallized in the *Megiste Syntaxis*, *The Almagest*, of Ptolemy, survived till the days of Kepler, and as a method of calculation still survives in the Harmonic Analysis of the modern mathematician. Animals, plants and minerals were studied both in the laboratory and in the open, and physical theories of the universe were begun.

But internecine strife and external wars first diverted the energies and later drained the life-blood of Greece, the race of giants died out, and the arduous study of nature waned or was displaced by vain disputes over Aristotelian logomachies, verbal subtilties and false analogies, or by the building of lofty castles-in-the-air, framed of Platonic ideas and raised on a flimsy foundation of will-o'-the-wisp etymologies, in either case leading to and ending in a barren philosophy of intellect. Then came all-conquering Rome whose genius was directed to organization for action, to military discipline and statute law, and science as abstract knowledge all but died out, although philosophy as a guide to right living still survived. Among the Romans, science, except as applied, was neglected and almost despised, yet strange to say he was a Roman who striving to turn his fellow-countrymen to the higher knowledge gave the world the grandest philosophical poem that has ever been written; it was a Roman, Titus Lucretius Carus, who wrote "De Rerum Natura," "On the Nature of Things," in which he taught the doctrine of the gravitation of all things terrestrial and that even flames would fall were they not forced upward by the heavier air.

> "See with what force yon river's crystal stream
> Resists the weight of many a massy beam,
> To sink the wood the more we vainly toil,
> The higher it rebounds, with swift recoil,
> Yet that the beam would of itself ascend
> No man will rashly venture to contend.
> Thus too the flame has weight, though highly rare,
> Nor mounts but when compelled by heavier air."

Anticipating Galileo's experiment and von Guericke's air-pump, he taught

> "In water or in air when weights descend
> The heavier weights more swiftly downwards tend.
> The limpid waves, the gales that gently play,
> Yield to the weightier mass a readier way;
> But if the weights in empty space should fall,
> One common swiftness we should find in all."

With the death of Lucretius (*c.* 55 B.C.), set the sun of Greek science; after him came the five centuries of twilight of the Roman Empire, followed by the thousand years of gloom of the middle ages. Here and there, and now and then a star peered through a rift in the clouds only to be quickly shrouded again. At last were born Leonardo da Vinci, (1452), the all-gifted Italian, and Copernicus, (1473), the silent deep-thinking Slav, twin heralds of the dawn of a new day.

OTTAWA, ONT.

MEETINGS OF THE SOCILTY

AT TORONTO

MEETING OF GENERAL COUNCIL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

AT METEOROLOGICAL OBSERVATORY, BLOOR ST. WEST, TORONTO, JUNE 12, 1914

Present:— Professor Chant, Professor DeLury, Rev. Dr. Marsh, Mr. Paterson, Mr. Strathy, Mr. Stupart, Dr. Watson, Dr. Wunder and Mr. Collins. First Vice-President, Dr. Watson, in the chair.

The meeting was specially called for the purpose of considering steps to be taken towards securing a Civic Astronomical Observatory in or near Toronto under the control of the Society and the University of Toronto, and in which students, citizens and visitors will have observational and other specified privileges.

In extension of the report, of the Committee having the matter in charge, which was accepted by Council on March 20, 1913, (the Committee then consisting of:— Professor Chant, Professor Stewart, John A. Paterson and Dr. A. D. Watson), a copy of a letter sent to the Commissioner of Parks of the City of Toronto in reference to granting a site for the proposed Observatory on City property on the brow of Bathurst St. hill, immediately north of St. Clair Ave., was read, together with a favorable reply to it on the part of the City.

It was the general expressed opinion of those present that a

sum of money in the neighborhood of one hundred and fifty thousand dollars would be required ($150,000) to erect and equip the proposed observatory, and that if properly approached, there are citizens of means who would appreciate the honor of having their names associated in a permanent way as contributors towards the establishment in our midst, of such a monument to Astronomical Science; an added strength to our great University, a permanent benefit to our Society and the citizens of the Province, as that proposed.

Before taking further action in the realization of the project, it was deemed well to have definite detailed information submitted and agreed upon in regard to :—

(1). The general administration of the observatory affairs and the status, obligations and privileges of all three bodies :— The Royal Astronomical Society, the University and the City of Toronto.

(2). The character, extent and equipment of the proposed buildings.

To this intent two sub-committees were appointed to investigate and report to the General Council at a future meeting.

The first committee to be known as the "General Administration Committee," consisting of :— Professor DeLury, Mr. John A. Paterson, Mr. Stuart Strathy, Professor Chant and Dr. Watson. Mr. Paterson as Convener.

The second committee to be known as the "Building and Equipment Committee" consisting of :— Professor Chant, Mr. H. B. Collier, Mr. J. R. Collins, Rev. Dr. Marsh, Dr. Wunder, Professor Stewart and Mr. A. F. Miller. Professor Chant as Convener.

Moved by Mr. Paterson, seconded by Dr. Wunder — That the Society's Gold Medal for the year be supplied to the Department of Astronomy in the University of Toronto.—Carried.

The meeting then adjourned subject to the call of the acting President.

J. R. C.

Ordinary Meetings: At Toronto

April 5, 1914.— The Meeting was held in the Rooms of the Society, 198 College Street, at 8 p.m.

Mr. E. F. Peel, Uxbridge, Ontario, was elected a member of the Society.

The lecture of the evening was given by Mr. Harry J. Lane, on "The Nature and Origin of Meteors."

A general description of the various classes of meteors was first presented, and the distinction between meteors and shooting stars given. The velocity of the meteors was demonstrated and the effect on the meteor of its passage through the air was described, the amount of heat developed was calculated and the process of disintegration due to this effect was given.

The resultant appearance of meteorites which strike the earth and cool off was described with the aid of a specimen which Mr. Lane showed. The peculiar features of the appearance were pointed out and their probable cause given.

The question of the origin and number of meteorites was then discussed. The various suggested origins were given and their probability considered.

Suggestions were made as to the methods of observation and recording so as to obtain the best results, that method being found to be the most satisfactory used by Mr. Lane in his own work on meteors.

Several members took part in an interesting discussion of the lecture. L. G.

At Ottawa

March 12, 1914.— The fifth meeting of the Spring Term was held at the Dominion Observatory this afternoon at 3 o'clock, Mr. R. M. Stewart presiding.

The programme for the afternoon consisted of brief abstracts presented by members of the observatory staff of recent advances in several branches of astronomy.

Mr. C. A. French reviewed recent work in the field of "Terrestrial Magnetism." With the aid of a map and lantern-

slides he showed the magnetic declinations for various points across Canada, pointing out localities having exceptional values due to local magnetization. He noted the relationship between diurnal range and the sun-spot numbers. The year 1913 was quiet magnetically, due to the scarcity of sun-spots.

Dr. R. K. Young then reviewed under the head, "Some Stellar Problems," the general results which have been deduced on the motions of stars and the relationship between radial and proper motions from which for a large group of stars, an average distance of from 400 to 500 light-years was deduced. He showed how a valuable and large amount of work could be done with the objective prism, even though at a loss of accuracy, which would be of great service in solving many general problems.

Mr. R. M. Motherwell then dealt with "Photometric Work and Comets." He mentioned the recently discovered comets, then reviewed the advances in photometric methods and measures relating to the brightnesses of stars. He dealt particularly with the extra-focal method which will soon be in operation here.

Mr. T. H. Parker outlined some work recently done by Adams using the 60-inch reflector at Mount Wilson, concerning the "Scattering of Light in Space." Lantern-slides of the spectra of stars at various distances showed a tendency to a gradual decrease in intensity of the violet end of the spectrum the farther the star was away. However he pointed out that other explanations could be given to account for this and showed how a large amount of such observations would be necessary to decide the question.

Dr R. E. DeLury, with the aid of lantern-slides, gave a brief review of the work on the magnetic field of sun-spots and the general magnetic field of the sun and also on the convection current in the sun-spots and in the solar atmosphere near the sun-spots, recently performed at Mt. Wilson by Hale and St. John, respectively.

March 20.—The sixth meeting of the Spring Term was held at the Dominion Observatory this afternoon at three o'clock Mr. R. M. Stewart presiding.

The meeting was a special one to take advantage of Dr. John A. Brashear's presence in Ottawa to have him relate some of his experiences. Dr. Brashear spoke of Dr. S. P. Langley and his work. He dealt with his early work on the sun with the bolometer invented by him; then with his pioneer work on flying machines and his work as Secretary of the Smithsonian Institution. The intimate acquaintance which had existed between Dr. Langley and Dr. Brashear enabled the speaker to give his hearers a clear insight into Langley's character and work. Dr. Brashear spoke quite sympathetically and sorrowfully of the accident to Langley's last flying machine. The publication by a revengful reporter of its failure broke Langley's spirit and hastened his death.

A hearty vote of thanks was tendered Dr. Brashear, after which the meeting adjourned.

March 26.—The seventh meeting of the Spring Term was held at the Dominion Observatory this evening at 8 o'clock. In the absence of the President and the Vice-President, Dr. J. S. Plaskett presided.

Dr. J. C. Glashan gave an address on "How Knowledge Grows"—the second on this subject presented by him to the Society. In this address Dr. Glashan dealt particularly with the use and value of hypothesis and theory, drawing most of his illustrations from modern times—though he freely referred to ancient times as well. He pointed out the errors of the ancients in building up hypotheses on few facts; and how their lack of mathematical skill and poor notation led them to make and leave untested many absurd assumptions. He pointed out how striving to answer the question "Why?" had been a great hindrance to science in all times. He showed how knowledge grew not from the finished product but rather from the great number of

failures and tests necessary in arriving at it. In conclusion, Dr. Glashan gave a clear account of Pasteur's work on the twin-crystals of tartaric acid, each the mirror image of the other, citing this as an example of the working of scientific intuition.

A hearty vote of thanks was given the lecturer after which the meeting adjourned.

April 9.—The eighth meeting of the Spring Term was held this afternoon at the Dominion Observatory at 3 o'clock. Mr. R. M. Stewart presiding.

Mr. W. A. Dier gave a lecture on "Electricity and Its Application to Telegraphy."

Mr. Dier dwelt at considerable length on the early work which paved the way for present day methods. He described in detail LeSage's electric telegraph, which was the first and dates as far back as 1774, in which frictional electricity was used, and 24 wires, as was also the case in that of Sommering, of Munich, in 1809. The first practical telegraph came after the discovery of the principle of the electro-magnet, first by Romagnesi, of Trente, in 1805; then independently by Oersted, of Copenhagen, in 1819; Sturgeon, of England, in 1825; and Henry, of Albany, in 1828. Morse devised a practical telegraph from Henry's work. Mr. Dier spoke of misconception on the part of the general public in regard to the technicalities involved in the modern telegraph equipment and showed by lantern-slides the great advances made in the past twenty years. He gave a clear explanation of Ohm's Law, upon which are based all electrical calculations and measurements. The galvometer was explained and methods for increasing its reading range. The comparative merits of gravity batteries, storage cells and dynamos as feeders for telegraph circuits was treated fully and reasons for the substitution of storage cell and dynamos for the gravity cell. The simple Morse circuit, the polar duplex by which two messages are transmitted simultaneously on the same wire; and the several systems of quadruplex were described, automatic

repeaters for use on long lines were fully treated, those described being the Milliken-Hicks, the Weiny-Phillips and Mr. Dier's own form, in which a direct-point arrangement eliminates the necessity of transmitters and which, therefore, is free from time-lag due to the mechanical and electro-magnetic inertia of the transmitter. At the end of the lecture the President stated that Mr. Dier's repeater has been found by tests at the Observatory, to be superior to all other forms. Some other features of the lecture were explanations of the methods used in locating "crosses," "grounds" and breaks in telegraph lines and cables, and the methods of measuring resistance.

After some discussion and comment in various points in the lecture a hearty vote of thanks was given Mr. Dier, after which the meeting adjourned.

April 23.— The ninth meeting of the Spring Term was held this evening at the Dominion Observatory, Mr. R. M. Stewart presiding.

Mr. C. P. Edwards, Superintendent of Radio-Telegraphy for the Dominion, was then introduced by the chairman, and he proceeded with his lecture on "Radio-Telegraphy."

Mr. Edwards introduced his subject by recalling some disasters at sea before the introduction of Wireless Telegraphy, and pointed out how quickly it brought out aid to the *Titanic*.

He outlined the historical development of the subject since the discovery of the waves by Hertz in 1888. He described the various kinds of coherers which had been used, and illustrated them by experiments. He showed how waves of any desired length were produced and detected, and why it became necessary to select a definite wave (2000 ft.) in practice. Resonance was illustrated by altering the length of the secondary circuit; and the analogy between the interaction of primary and secondary to the interaction of two pendulums swinging on the same support was clearly shown by experiments. Some phonograph records of messages across the Atlantic received at Glace Bay

were reproduced through a phonograph horn which made them quite audible throughout the lecture room. By connecting to the Observatory receiving apparatus, a message from Kingston was reproduced in the same way. The message ran : " Kingston Wireless sends compliments to the R. A. S. C. and wishes them every success in their scientific pursuits." In the same manner the Arlington Time signals from 9.55–10.00 were reproduced and a phonograph record of their Weather Report was taken and reproduced.

By charts Mr. Edwards showed how the ships at sea were connected by wireless to one another and to the land stations. He stated that there were 93 stations (land) and 57 ships under the Radio-Telegraphic organization of the Dominion of Canada.

After a hearty vote of thanks was tendered the lecturer the meeting adjourned. Many took advantage of the clear night to view objects through the 15-inch telescope.

May 22.— The tenth meeting of the Spring Term was held at three o'clock to-day in the Dominion Observatory, Mr. R. M. Stewart presiding.

Mr. W. E. Harper was then called to give his address entitled " Atmospheric Conditions Suitable for the Large Reflector."

Mr. Harper outlined the factors considered important for observations with a large reflector and the question to be decided was " Where in Canada can a six-foot reflector be placed to best advantage?" Clear sky, small nightly temperature range, steady seeing, accessibility, suitability for living, electric power, etc., were necessary. He outlined the work in selecting the sites of the Lick, Yerkes, Mills and the Solar Physics Observatory of the Carnegie Institution before describing the steps taken in regard to the Canadian site. Meteorological Reports were first consulted and a table of the best locations was prepared. The places selected for preliminary investigation were Ottawa, Medicine Hat, Banff, Penticton and Victoria ; in this connection

valuable suggestions were received from Mr. R. F. Stupart, Director of the Dominion Meteorological Service. It was decided to view close double stars with the 4½-inch Cooke telescope to test the seeing and to test the transparency by naked eye observations and faint objects with the telescope. An amemometer, a thermograph, and a hygrometer were taken along also.

The places were visited as follows in 1913 :— Medicine Hat, last half June ; Banff, first half July ; Penticton, last half July ; Victoria, August ; Penticton, first three weeks in September ; Medicine Hat, last week in September, first week in October ; Ottawa, May and June, two weeks in October and first week in November. In August a short trip was made to the Lick Observatory and in October to Yerkes Observatory for the purpose of comparing the seeing at these places with that at the Canadian points. On a scale of 5 for "perfect seeing" the various places were ranked as follows : Medicine Hat, 2·8 ; Banff, 1·3 ; Penticton, 3·0 ; Victoria, 3·8 ; on the return trip, Penticton 3·2 ; Medicine Hat, 2·1 ; Ottawa, 2·6. Then the choice came down to Victoria and Ottawa and these locations were compared for winter conditions, Victoria in December and Ottawa in January. The comparison shows :—

Ottawa seeing, summer 2·6 ; winter 2·3 ;
Victoria seeing, summer 3·8 ; winter 3·3 ;

wind, the same ; percentage of cloudy weather, the same ; average nightly temperature range, Ottawa 7°·6, Victoria 3°·8 F. This last point added to the fact that Victoria's seeing is 50 per cent. better than Ottawa's led — after consultation with several eminent astronomers — to the selection of Victoria.

The speaker commented briefly on the possible sites in the vicinity of Victoria examined by him, such as Mt. Douglas, Mt. Newton, Saanich and others, and advanced reasons for the selection of Little Saanich.

After the President extended the thanks of the Society to Mr. Harper the meeting adjourned.

R. E. DEL.

AT REGINA

May 15, 1914.— Professor J. L. Hogg, M.A., Ph.D., of the University of Saskatchewan, addressed the Centre on "The Origin and Some of the Uses of Wave Motion."

The following is an outline of the lecture:

The corpuscular and the wave method of transferring energy from one point in space to another were briefly explained, emphasis being placed upon the significance of the terms vibration, wave, wave-length. By means of lantern slides the manner in which waves from two sources, which are vibrating alike, may interfere with each other was described, and the conditions under which interference may take place discussed. Several lantern slides were shown which indicated that two sources of illumination also send out something which resembles waves at least in this, that the light from one source may interfere with that from another. The property which waves of water and of sound possess of being able to pass round behind obstacles was shown to be possessed also by these light waves. Slides were shown indicating that light does pass in behind the opaque object. The white spot in the shadow of a circular opaque disk, and the white lines in the shadow of a hair were shown illustrating this point.

It was pointed out that in the case of water waves, and sound waves it is easily learned what are the oscillators, or vibrating bodies, which are the sources of the waves, but in the case of light, it is only in recent years that anything definite has been learned about the nature of the oscillators which give rise to light-waves. In 1896 the discovery was made by Zeeman that when a source of illumination is placed in a strong magnetic field the nature of the light being emitted is changed. In the case of a line spectrum, new lines appear when the field is made to act upon the source of light. Lorentz immediately pointed out that this result could be explained in terms of a theory which he had put forward previously that the oscillators are electrons, or small negatively electrified particles. He showed that if a negative particle were describing an orbit about a

centre of attraction a magnetic field might be made to act upon it in such a way as to increase the force drawing this particle to the centre thus resulting in a diminution of the period of oscillation of the particle, or it might be made to act so as to diminish the force to the centre, thus increasing the period of oscillation. The former would result in light of a shorter wave-length, and the latter in light of longer wave-length, being emitted than that which would be emitted by any such oscillator in the absence of the magnetic field. Thus the effect of a source of illumination in a given field would be to resolve a given line in the spectrum into components, which is just the result obtained by Zeeman. Moreover, it appeared after the properties of Cathode rays were better understood, that the charge carried by each of these oscillators must bear the same ratio to its mass, as the charge of the cathode particle bears to its mass in order that the displacements of the components should be in agreement with experimental results. Further experimental work, indeed, has shown that the whole phenomenon is a very complex one not explicable in terms of any theory at present available, but, notwithstanding this, there is sufficient evidence to lead us to believe that the oscillators which give out the light which is found in a line spectrum at least, on the electrons, which are now believed to form an important part of the atoms of all bodies.

Attention was also called to the effect of ultri-violet light upon metals in causing them to emit electrons, and it was shown that here a difficulty arises in accepting the view that light energy is uniformly distributed around the light giving source, as the energy required to cause the emission of an electron could not be taken in in the time elapsing between the incidence of the light and the emission of the electron. The full investigation of this phenomenon will probably greatly extend our knowledge of the origin and nature of light-waves.

There was a good attendance and the address was highly appreciated.

A. J. P.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

April

Temperature.— In British Columbia, Alberta and the greater part of Saskatchewan, the month was warmer than average. In Manitoba, however, and eastward to the Atlantic, mean temperatures were everywhere below average, the negative departure in Manitoba varying from 1° to 3°; in Northern Ontario, the Ottawa Valley, Quebec and most of the Maritime Region from 3° to 7°, while in Southern Ontario, and Southern and Southwestern Nova Scotia the negative departure was less than 3°. In the Prairie Provinces, the weather was cold during the first decade, but after the 10th it was generally quite mild, except for two cool waves of short duration. Temperatures of from 70° to 79° were recorded at many places in Saskatchewan and Alberta on the 15th, and temperatures of 60° and over were of frequent occurrence. In Ontario, generally cold, unsettled weather prevailed during the first part of the month. After the 14th, however, the weather in the southern and western parts of the Province was generally favorable. In Quebec and the Maritime Provinces the first half of the month was cold, while during the latter half alternate cool and mild periods prevailed.

Precipitation.— The precipitation for the month was below normal in nearly all sections from British Columbia to the Lake Superior region, only from one-third to three-quarters of the normal fall occurring over the greater part of the Prairie Prov-

inces, and Medicine Hat recording little or none. The greater part of the precipitation in these provinces occurred during the latter half of the month. In Southern and Eastern Ontario, however, the fall was above average in nearly all districts, as it was also locally in the Middle St. Lawrence, and in the northern and eastern sections of the Maritime Provinces. Some heavy local rains occurred towards the close of the month in Ontario; a severe storm of rain, sleet and snow passed over the Maritime Provinces on the 2nd, and a heavy snowstorm occured in Cape Breton on the 6th.

May

Temperature.— The month was warmer than average in nearly all parts of the Dominion. In Southwestern British Columbia the positive departure was between 2° and 3°, and no frosts occurred in the agricultural sections of the Province. Throughout the greater part of the West mean temperatures were from 1° to 4° above normal; in Northern Alberta, however, and in Southeastern Saskatchewan there was a slight negative departure from the normal temperature. Frosts were general in Alberta and Saskatchewan on the mornings of the 6th and 7th, and again in many parts of the West from the 10th to the 14th. Warmer weather then set in, and on the 24th, 25th and 27th maximum temperatures were in the neighborhood of 80° in many districts. In Southern and Eastern Ontario temperatures ranged from 2° to 5° above normal, and from 5° to 6° above in the Lake Superior region. Frosts were almost general in the Province on the 1st and 2nd, and maximum temperatures of over 80° occurred in many districts on the 19th, 20th and 21st. In Quebec, the month was 3° and over, warmer than average throughout the populous part of the St. Lawrence Valley; in the Gaspé Region, however, the positive departure from normal was somewhat less, and in parts of the eastern townships temperatures were about normal. In the Maritime Provinces mean temperatures were above normal in some districts and below normal in others, but the departures were nowhere great.

Precipitation.— Precipitation for the month fell seriously below the normal amount in Southwestern British Columbia, but in the interior of the Province there was abundant rain. In Southwestern Saskatchewan and Southern Alberta there was a serious drought, only from one-tenth to one-quarter of the normal fall occurring, but in most other parts of the West there was an excess. In Ontario the rainfall was only from one-quarter to one-half of the normal amount over the greater part of the Province; the Lake Erie and adjacent counties, however, reported more than the average amount, several heavy rains occurring in these districts. Likewise, in Quebec, the rainfall was below normal, only from one-half to two-thirds of the normal amount in the populous part of the Province. An interesting feature of the month was the dry spell from the 15th to 22nd, during which forest fires were widespread. In nearly all parts of the Maritime Provinces less than the average amount of rain fell, but Halifax and vicinity reported an abundance.

Temperatures for April and May, 1914

Station	April		May	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	58	10	74	20
British Columbia				
Atlin	52	- 2	68	24
Agassiz	72	31	85	36
Barkerville	56	18	70	23
Kamloops	78	26	86	35
New Westminster	70	31	84	39
Prince Rupert	68	36	77	38
Vancouver	65	35	82	31
Victoria	64	35	81	42
Western Provinces				
Battleford	75	15	85	27
Broadview				
Calgary	72	16	82	22
Carman				
Edmonton	72	7	78	29
Medicine Hat	76	20	90	26
Minnedosa	70	3	80	22
Moose Jaw	79	9	87	16
Oakbank	65	7	81	25
Portage la Prairie	66	7		
Prince Albert	68	4	81	26
Qu'Appelle	70	5	82	20
Regina	73	10		
Swift Current	76	10	86	18
Winnipeg	66	8	82	22
Ontario				
Agincourt	72	19	87	30
Aurora	74	17	86	28
Bancroft	68	10	86	23
Barrie	71	17	86	31
Beatrice	70	12	80	26
Birnam	80	17	86	29
Bloomfield	68	17	80	30
Brantford	76	16		
Bruce Mines				
Chatham	83	20		
Clinton	80	17	87	25
Cottam	82	14	90	24
Gravenhurst	73	12	83	25
Guelph	76	15	88	31
Haliburton	70	6	86	22
Hamilton	80	22		
Huntsville	72	10	83	26
Kenora				
Kinmount	69	1	89	23
Kingston	64	17	77	30
Lakefield	70	15	87	32
London	81	16	89	28
Lucknow	79	14	85	22
Madoc	69	15	87	31
Midland	70	11		
North Gower				
Otonabee				
Ottawa	68	14	88	33
Owen Sound				
Paris	81	19	90	32
Parry Sound	73	11	82	26
Peterboro'	67	16	87	29
Port Arthur	62	4	82	28
Port Burwell	73	18	76	30
Port Dover	71	19	82	31
Port Stanley	64	20	75	30
Ronville	61	9	83	27
Sarnia				
Southampton	77	18	88	28
Stonecliffe	68	6	90	24
Stony Creek	80	22	85	33
Stratford				
Toronto	67	21	87	35
Uxbridge	69	17	88	20
Wallaceburg	80	19	85	36
Welland	77	20	88	33
White River	62	15	81	10
Quebec				
Brome	71	11	84	26
Father Point	46	10	74	22
Montreal	74	14	88	24
Quebec	56	13	84	20
Sherbrooke				
Maritime Provinces				
Charlottetown	56	8	72	28
Chatham	64	2	90	24
Dalhousie	55	8	90	21
Fredericton	70	5	90	26
Halifax	70	18	88	26
Moncton	65	4	83	28
St. John	60	16	78	27
St. Stephen	74	5	92	24
Sussex	69	2	84	23
Sydney	62	3	75	25
Yarmouth	60	22	74	30

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P. T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1914	P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm	h m	
1346	Apr. 9	4 36·2	4 40·7	4 42·3	5 18·5	0·2	0 42·3	
1347	" 11	16 49·1?	16 59·9		19 48·4		2 49·3	Paper changed at 17h 36m. Possibly two separate quakes.
1348	" 20	13 38·9	13 50·9	13 57·2	15 48·6	2·7	2 09·7	4,440 km.
1349	" 22	21 56·6			22 0·9	0·05	0 4·3	Doubtful.
1350	" 24	8 50·3	8 52·9	8 53·4	8 58·3	0·3	0 8·0	Eq. reported from Reno, Nevada.
1351	" 24	22 41·2			22 43·2	0·1	0 2·0	
1352	" 25		8 36·0		8 58·5	0·1	0 22·5	Uniform thickening.
1353	May 8	12 49·9	13 04·7		13 23·3	0·2	0 33·4	Uniform thickening.
1354	" 19	0 34·9	0 41·1) 0 49·8)		1 22·1	0·3	0 47·2	Marked small disturb.
1355	" 19	22 7·9?	22 12·1	Air Currents		0·05		
1356	" 26	14 45·5	15 10·2) 15 29·2)	16 20·6	17 57·0	1·6	3 11·5	L.W. lasted a long time.
1357	" 28	3 36·7	3 43·7	3 44·7	4 33·6	1·8	0 56·9	Eq. at Panama 10.25 p.m. of 27th lasting 39 seconds, S.W. to N.W.
1358	" 28		18 12·4) 18 17·4)	18 17·8 18 20·2	18 49·7	0·3) 0·3)	0 37·3	Friendly Islands, S. Pacific.
1359	" 28	19 3·5?	19 11·3	19 12·3	19 36·3	0·2	0 32·8	May be merged into 1358.
1360	" 29	5 57·2?	6 8·7	6 14·8	7 15·8	0·2	1 18·6	P.Ts. doubtful. No defined max.

Period 17·7 seconds. 1 mm. = 0″·59.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1914	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1347	Apr. 9	4 22·9	4 29·7	4 36·7	5 6·0	0·4	0 43·1	Uniform thickenings.
1348	" 11	16 46·0	17 12·7) 17 15·0)	17 20·6		8·0		Merged into 1349.
1349	" 11	18 49·82	19 3·3	19 5·2	19 31·2	0·7		
1350	" 13	4 22·0			4 27·0	0·05	0 5·0	Minute thickenings.
1351	" 14	3 34·1		3 38·6	3 45·8	0·3	0 11·7	Mark'd grad. thick'ng
1352	" 20	13 39·5	13 47·5) 13 53·5)	14 9·9	15 25·7	0·8	1 46·2	
1353	" 24		8 38·6	8 39·6	9 3·1	1·3	0 24·5	Abrupt beginning. (Eq. reported from (Reno, Nevada.

No returns from Victoria since the 30th April.

Period 18 seconds. 1 mm. = 0″·54

J. Y.

MAGNETIC OBSERVATIONS

The photographic records obtained at the Observatory, Agincourt, showed for the most part nearly normal conditions during April and May, but disturbances were recorded as follows: —

From April 6th to 8th, disturbance of considerable magnitude; 8th to 11th, uneasy movements; 18th, light disturbance.

From May 6th to 7th, uneasy; 15th to 17th, light disturbance; 25th to 26th, light disturbance; and on 31st disturbance of magnitude.

Declination W.

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes--Mean Daily	
							From hourly readings	From Means of Extremes
1914	° ′	° ′		° ′		′	′	′
Apr.	6 23·3	6 46·7	6	5 52·6	7	54·1	10·9	16·4
May	6 22·8	6 34·0	26	5 34·9	31	59·1	10·4	14·6

Horizontal Force —C.G.S. Units

1914								
Apr.	0·160877	0·161732	6	0·159491	6	0·001476	0·000334	0·000553
May	0·160915	0·161769	31	0·159905	31	0·001864	0·000314	0·000504

Inclination

Month	Mean Earth Inductor
1914	° ′
April	74 41·4
May	74 40·4

ASTRONOMICAL NOTES

RADIATION OF THE SUN.—About 700 determinations of the solar constant of radiation have been made by the Astrophysical Observatory of the Smithsonian Institution, some at Washington at sea level; others at Mount Wilson, at an elevation of about one mile above sea level; others at Mount Whitney, at an elevation of nearly three miles; and others at Bassour, Algeria, at an elevation of three-quarters of a mile. No differences beyond the reasonable errors of measurement are found between observations made at two stations on the same day, whether made at sea level or at any of these stations, up to the elevation of Mount Whitney, 14,500 feet above sea level. Hence it appears that the method of estimating atmospheric transmission is probably sound. The mean value of the solar constant of radiation, as thus found from 700 determinations, is 1·933 calories per square centimetre per minute. By this is meant that if the sun's rays outside the atmosphere could be absorbed completely in a layer of water one centimetre (about three-eighths of an inch) thick, exposed at right angles to the solar beam, this layer of water would be warmed 1°·93 C. during each minute of time. Expressed in another way, the sun's radiation outside the atmosphere would be able to melt a layer of ice 105 feet thick each year.

An extremely interesting feature of the measurements has been that they show a variation of the sun. This conclusion has been tested in every way, not only by making measurements at different altitudes, but by comparing results obtained on the same days at Mount Wilson, in California, and at Bassour, Algeria. As these stations are separated by about one-third the circumference of the earth, it seems not possible that they could be generally influenced by local conditions in a way to dis-

turb the measurements in the same direction at the same time. Nevertheless, the results of about 50 days of simultaneous observing at the two stations agree in showing that when the radiation of the sun is found above the normal, at the one station, it is found also above the normal at the other station, and *vice versa*. The fluctuations of the intensity of the sun's radiation outside the atmosphere thus indicated range over about ten per cent. Often within a single week, or ten days, a fluctuation of radiation as great as five per cent. is shown. The variation of the sun in these short periods appears to be irregular, both as regards the magnitude of the variation and as regards the period of it.

The measurements made at Mount Wilson, which extend over the years 1905 to 1913, indicate also a fluctuation of the intensity of solar radiation, attending the changes of the number of sun-spots. There appears to be about three per cent. increase of the solar radiation outside the atmosphere, for an increase of 100 in the Wolf sun-spot numbers. It is a very curious thing that the solar radiation increases with increasing numbers of sun-spots, whereas the temperature, which directly depends upon the solar radiation, falls with increasing numbers of sun-spots. It appears that there is, attending sun-spots, a direct and an indirect influence on terrestrial temperature. The direct influence is due to the increased solar radiation. The indirect influence is, perhaps, due to a change in cloudiness, but as yet is not certainly understood. These two influences are of almost equal magnitude in general, but with the indirect influence, which tends to lower temperatures, slightly predominating. It will be a research of great interest and value to determine the cause of the indirect influence.—C. G. Abbot, (Director Smithsonian Institution, Washington), *Journal Franklin Institute*, No. 6.

The Problems of the Moon's Motion.—The researches of the last few decades into the motions of the moon and planets have resulted in showing some clearly defined differences between theory and observation. At the present time three of these seem to admit of few doubts as to their real existence. The

observed motion of the perihelion of Mercury is some 40″ greater than its theoretical value, and the moon exhibits two oscillations from unknown sources, one with a period between 250 and 300 years and a co-efficient of 10″ to 15″, the other with a period of 60 to 70 years and a co-efficient of some 3″. Other differences are more doubtful: the secular acceleration of the moon's mean motion appears to be greater than its theoretical value by about 2″ per century in a century, while there is evidence that its node or the mean motion of the earth shows a similar change. There are, besides these greater changes, small terms of much shorter period in the moon's motion which are not quite satisfactorily accounted for, but some of which have lately yielded to a more careful comparison between theory and observation. . . . .

In the first place, the gravitational theory of these accelerations admits of scarcely any doubt; any errors or changes could only amount to a fraction of a second. We are thus forced to assume the existence of unknown masses or forces. The moment this is done, accelerations of the mean longitude of the moon and of its node are equally probable: those which proceed from known causes are of the same order of magnitude. An acceleration of the earth's mean longitude of the same size appears less probable, partly on account of the earth's greater mass and partly because most of the known secular and long period terms, when present in the motions of both bodies, are of a quite different order of magnitude. In most of the discussions which have taken place, the evidence furnished by such points in the theory has been quite neglected. If we are searching for causes, such evidence is valuable in that it limits the range of possible hypotheses. This evidence, therefore, tends to show that nearly the whole of the outstanding acceleration must be put on to the moon's node, and that tidal retardation plays a comparatively small part in the phenomena. It should be added that there may be an acceleration of the perigee of similar amount without touching the question of the satisfaction of ancient eclipses. . . . . .

I must leave aside, on this occasion, the various hypotheses

which have been, and can be, brought forward to account for the large and well-determined differences between theory and observation. Some of these are easily taken out of the realm of probability by a brief examination of the theory. Others which explain one term only or which replace one discordance by another are of little value as working hypotheses. The secret is more likely to be disclosed by the discordance which requires the largest force to produce it. This force is roughly measured by the amount of change which it can produce in a given time, and the fluctuations which should be most carefully examined are neither the secular changes nor the great empirical term, but the oscillation which goes through all its phases in from sixty to seventy years.—E. W. Brown, in *The Observatory*, No. 474.

Halley's Comet of 1910.—In connection with this account of Halley's Comet and its near approach to the earth, it may be appropriate to add some remarks on the probable encounter of the earth with a portion of the tail at, or closely following, the time the comet transited the sun. Indeed, it seems more than probable that the earth actually did encounter one of the branches of the tail—the southern branch—on, or about, May 18 or 19, and more probably on the later date. There is also a suspicion that the influence of this encounter (if such there was) on our atmosphere was apparent for months afterward.

The double tail seen here on the nights of May 17 and 18, the lower, and probably larger branch of which widened toward the southeast horizon, involved the ecliptic, as will be seen by the diagram in *Astrophysical Journal*, and without doubt extended beyond the earth. There are strong chances that the earth passed through this part of the tail about May 19. That the tail was long enough to reach to the earth is shown by the fact that as late as May 25 its length (54°) was over thirty million miles, or twice the distance of the comet at its nearest approach to us on May 18. . . . . .

The forenoon of May 19, however, developed peculiarities

that were very suggestive (*Astronomische Nachrichten*, CLXXXV, 229, 1910). Briefly, these consisted of a peculiar iridescence and unnatural appearance of the clouds near the sun and of a bar of prismatic light on the clouds in the south. This, combined with the general effect of the sky and clouds — for the entire sky had a most unnatural and wild look — would have attracted marked attention at any other time than when one was looking for something out of the ordinary. The sky had been watched carefully during the forenoon of this date but nothing unusual had appeared until close to noon, when the conditions became abnormal, as stated above. Of course this unusual phenomenon, if seen only at one place, might be considered a co-incidence, but something similar was reported on that date at other widely distant places. (See *Transvaal Observatory Circular*, No. 3, p. 19).— E. E. BARNARD, in *Astrophysical Journal*, No. 5.

HARVARD COLLEGE OBSERVATORY.— The principal work of the Henry Draper Memorial is the Revised Draper Catalogue. Miss Cannon continues to classify five thousand spectra a month, and has now classified 100,155. A little more than half of the sky is covered, so that the total number of stars, excluding duplicates, will probably be somewhat less than two hundred thousand. Many of them are fainter than the ninth magnitude, and some are not in the Bonn or Cape Durchmusterung. Copy for the printer has been prepared for the first hour of right ascension, and contains about five thousand stars. All of the photographs have been taken with the two similar doublets, the 8-inch Draper for the northern and the 8-inch Bache for the southern stars. Nearly all the spectra in the region extending from 0^h to 9^h, and about one-third of the northern spectra in the remaining hours of right ascension have now been classified. The number of photographs taken during the year with the 8-inch Draper Telescope is 565, making 38,580 in all. 7,225 stellar photographs were taken here. The total number in the Harvard collection is about 220,000.

The 11-inch Draper Telescope is in regular use by Professor

W. H. Pickering in Jamaica. The excellence of the atmospheric conditions permits valuable observations to be made visually. The principal investigations undertaken were the periodic changes in ellipticity of the disks of Jupiter's four larger satellites, an application of the same method to very close double stars, bright streaks and evidence of present activity in craters of the moon, and the meteorological and seasonal changes of Mars. An interesting conclusion is that Jupiter's satellite's like Saturn's Ring consist of meteors. The changes in shape of the first satellite indicate the existence of two sets of tides.—From *Director's Report* for 1913.

THE ZEEMAN AND STARK EFFECTS.—The important discovery by Stark of the effect of an electric field on radiation is of the greatest interest to the physicist, and may prove of equal value to the astronomer. Although the observed phenomena are in some respects closely analogous to those of the Zeeman effect, there are significant points of distinction which makes it possible to determine with certainty whether an electric or a magnetic field is the producing cause. The most important criterion, in cases where the magnetic or electric fields are too weak to produce complete separation, is afforded by the fact that whereas in the Zeeman effect the outer components of a magnetic triplet are circularly polarized when observed in the direction of the lines of force, the components of an electrically resolved line are unpolarized under similar conditions of observation. Thus, disregarding other points of difference, the presence of circularly or elliptically polarized light, if not of instrumental origin, will serve as a sufficient criterion. . . . . .

At present it can only be said that if the Stark effect exists in the sun its magnitude appears to be so small that special methods, similar to those employed in the study of the general magnetic field, will be required to detect it. Polarizing apparatus suitable for this purpose is described in a paper read before the American Philosophical Society on April 24th.—GEORGE E. HALE, *Publications Astronomical Society of the Pacific*, No. 154.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERY

It is well known that potter's clay is magnetic with a north and south pole thrown in by the magnetic currents of the earth. This line of poles will remain constantly parallel to these currents no matter how, by handling, you may twist around the mass of clay. But, if you bake the latter, the poles become permanent, registering the declination and the inclination of the magnetic currents of the epoch. Consequently, I would believe that in a contact of diabase (which is a lava) with a clay bed, we may expect to find a certain thickness of baked clay registering the exact position of the currents of the date, supposing the strata are undisturbed. Would there be there an indication of the diabase irruption? It might be objected that the cycle of variations of the magnetic needle has been covered over and over again. Granted, but nevertheless, in accordance with some personal ideas of mine, you might have here a surprise: you may register some great and quite unexpected declination. Now, if I am right, what I wish to know is this: Will our present delicate instruments permit us to read this contact so as to find scientifically accurate data on the existence and direction of the magnetic currents of the date of irruption of the diabase?—ANDRE, (Ottawa).

ANSWER

I have been unable to obtain any information relating to the subject of this query. A competent expert on clays questioned the correctness of the statements in the first few sentences, and would be greatly obliged to learn on what authority they are made. Perhaps "André" would give further information.

AN EXTENDED METEORIC DISPLAY IN 1783

In his interesting article in the last issue of the JOURNAL Mr. W. H. S. Monck, of Dublin, Ireland, referred to a meteoric

display in 1783 which in some respects resembled the notable display of February 9, 1913. At my request Mr. Monck has sent me an account of it, as follows :—

EXTRACT FROM *ANNUAL REGISTER*, 1783

18th August,—At eleven minutes past nine in the evening, a very singular phenomenon was seen at Greenwich. It being rather dark a sudden and uncommon light appeared, without any cause then visible, for full two minutes: then appeared this phenomenon coming from the N.N.W perfectly horizontal in its course and without any vibration continued to S.S.E. It passed over Greenwich and near the Royal Observatory till the elevated trees in the park took it from the sight. Though it was transitory the motion was not rapid for you could distinctly discover its form, colour, etc. Its duration was near two minutes during which there was no variation in its lustre. Its magnitude and animated effect made it appear near our earth. Two bright balls parallel to each other led the way, the apparent diameter of which appeared to be about two feet, and were followed by an expulsion of eight others not elliptical seeming gradually to mutilate, for the last was small. Between each ball a luminous serrated body extended and at the last a blaze issued and terminated in a point. Minute particles dilated from the whole. While this luminary was passing the atmosphere was exceedingly bright but immediately after it became dark though the moon was up. The phenomenon which appeared in 1716 and continued from eight in the evening to three in the morning was like the present not local, for it has been seen in most parts of the Kingdom, notwithstanding it was not subject to the great vibrations of the former. The balls were partially bright as imagination can suggest, the intermediate spaces not so exquisite in their colourings. The balls were tinted first by a pure bright light, then followed a tender yellow, mixed with azure, red, green, etc., which with a coalition of bolder tints and a reflection from the other balls gave them the most beautiful rotundity and variation of colours that the human eye could be charmed with. The sudden illumination of the atmosphere, the form and singular transition of this bright luminary rendered much to make it awful; nevertheless, the amazing vivid appearance of the different balls and other rich connective parts not very easy to delineate gave an effect almost equal to the rainbow in the full zenith of its glory. It appeared also almost all over the island of Great Britain, nearly at the same time, as well as France, Flanders, etc.

In a note accompanying this Mr. Monck makes some interesting remarks which I take the liberty of quoting :—

"There is plenty of fine words but I don't think you will be able to follow it very closely but some of the agreements may strike you. See a note in the 'Supplemental Catalogue of

Ærolites,' for August where Mr. Harvey inserted a fall of an ærolite at Shetland on August 18, 1783. Shetland would be pretty much in the N–N–W line, from Greenwich, but I do not know what Mr. Harvey's authority for the fall was. I think the path of this meteor of 1783 was computed from observations.

I don't know what the phenomenon of 1716 referred to in the *Annual Register* was, but I think from the description that it must have been an aurora, not a meteor. The volume for 1783 has another interesting article in it — the discovery by Mr. William Herschel of a new star called Georgium Sidus — the name which he originally gave to Uranus."

ROTATION IN A NEBULA DETECTED

One can hardly look at the beautiful photographs of spiral nebulæ which have been made in recent years without being impressed with the notion that they are in rotation. The graceful arms encircling the mighty central mass must surely be moving about it, and perhaps, a hundred or a thousand years hence, a comparison of direct photographs taken then with our own will easily reveal this motion.

But there is another way to detect motion of the heavenly bodies, namely by the spectrograph. It was applied with great success to determine the rotation of the sun, Jupiter and Saturn, and, a few years ago, Uranus was shown by photographs taken at the Lowell Observatory to have a rotation period of about ten and one-half hours, a result agreeing well with what had long been surmised.

It has fallen to Dr. V. M. Slipher, of this same observatory, to make the important discovery of rotation in a nebula. Such bodies are so faint that it is extremely difficult to obtain a spectrogram, but with an especially efficient spectrograph attached to the 24-inch refractor photographs were obtained showing unmistakable inclination in the nebular lines, and hence demonstrating rotation.

The nebula which has yielded this result is one in the con-

stellation of Virgo, catalogued as N. G. C. 4594. In Plate V. is a picture of this object from a direct photograph by Mr. C. O. Lampland, taken with the 40-inch reflector of the Lowell Observatory.

In *Bulletin* No. 62, of the Lowell Observatory, Dr. Slipher gives the following information :—

> A spectrogram of the Virgo Nebula, N. G. C. 4594, made a year ago showed the nebular lines to be inclined. A second plate was immediately undertaken but failed, through exasperating circumstances, of a sufficient exposure — although it verified as far as it went, the inclination; and I resolved to withhold any announcement until a second satisfactory plate might be obtained. This observation is now available and fully confirms those of a year ago. The inclination of the lines which is analogous to that produced by the diurnal rotation of a planet, is unmistakable and leads one directly to the conclusion that the nebula is rotating about an axis. Although from the time of Laplace it has been thought that nebulæ rotate, this actual observation of the rotation is almost as unexpected as was the discovery that they possessed enormously high radial velocities. The fact that this nebula has a radial velocity of fully a thousand kilometers per second, as established here a year ago, makes it not so surprising that it should also be rotating rapidly.
>
> The slit of the spectrograph was placed over the long axis of the nebula which is of the "spindle" type and hence the observation shows clearly that such nebulæ are -- as previous evidence tended to show -- spirals seen edge-wise. . . . .
>
> The discovery of the rotation of this nebula has opened a new field for investigation and that further observations will disclose other nebulæ to be in rapid rotation may be confidently expected. The numerous spectrograms of nebulæ that have been secured here contain a few with indications of inclined lines, among them those of the great Andromeda Nebula.

From the above it would appear that the axis about which this nebula rotates is in the north-south direction, which is vertical as shown in the picture.

WHAT IS THE CONDITION OF MATTER AT THE CENTRE OF THE SUN?

According to our present views, at the centre of the sun the temperature must be extremely high and the pressure enormously great. Is the matter there, gas, or liquid or solid? The researches of Andrews and others seemed to show that for each

PLATE V.

SOUTH

NEBULA IN VIRGO, N. G. C. 4594,

Which has been shown by V. M. Slipher to have a motion of rotation.

Photographed, April 18, 1911, by C. O. Lampland, with the 40-inch Reflector of the Lowell Observatory.

substance there is a critical pressure and a critical temperature. If a body were heated above a certain temperature it must be a gas, and no amount of pressure could make it a liquid or a solid.

But some recent experiments at Harvard University by Mr. Percy W. Bridgman have given us new results. By means of specially designed apparatus he has obtained pressures as high as 30,000 to 40,000 kilograms per square centimetre, or 15 or 20 times as high as the pressures in modern artillery. He shows that the theories hitherto proposed do not hold at high pressures. A liquid can probably be reduced to a solid by the application of sufficient pressure, no matter how high the temperature.

Mr. Bridgman obtained several remarkable results. Of particular interest are new forms of ice which are denser than water. Yellow phosphorus at a pressure of 12,000 kilograms and temperature 200° C. was changed to a form which looked like graphite and which was 15 per cent. denser than the densest red phosphorus.

These results give us some explanation why the earth is as rigid as steel, and provide a firmer physical foundation for our theories of the sun.

PLEASANT MEMORIES OF DR. THOMAS DICK

Readers of the JOURNAL will remember the very pleasing account of a visit to the home of the late Dr. Thomas Dick which appeared in the first issue of 1913, and will be interested in the following letters.

DR. BRASHEAR TO THE EDITOR

PITTSBURGH, PA., April 10, 1914.

MY DEAR PROFESSOR CHANT:—

When I was on my recent visit to California, and to Lick and Mt. Wilson Observatories, as the guest of Mr. Swasey, I met some very pleasant people, and we were received with the greatest kindness and consideration, particularly by the astronomers whom we met. In San Francisco the Engineers gave us a little dinner, having as the presiding officer of the evening Mr. G. W. Dickie, Vice-President of the American Society of Naval Architects and Marine Engineers. Mr. Dickie was at the head of the Union Iron Works when and where the great

dome of the Lick Observatory was constructed. In his after-dinner address, he spoke of the pleasure of meeting those who were interested in astronomy and told us a most interesting story of his knowing "our hero," Dr. Thomas Dick, the old Scotch astronomer; how he had helped him devise a telescope mounting, and also as to how and where he could get a lens, and then afterward taught him how to use the instrument and study the heavens.

Of course, his address was a great delight to Mr. Swasey and myself, because he was the first man we had ever met who *personally knew Dr. Dick*. I wish I could remember all his story, as it was interesting from beginning to end, particularly since I had made a visit to the home of Dr. Dick, an account of which you published in your JOURNAL of January-February, 1913. I told Mr. Dickie I would send him a copy of the article that you had so kindly published, and I am sending you the original letter received from him in response, which you may give to your readers if you like.

With all good wishes, believe me,

Very cordially yours,

(Signed) JNO. A. BRASHEAR.

MR. G. W. DICKIE TO DR. JOHN A. BRASHEAR

SAN FRANCISCO, CAL., January 12, 1914.

DR. JOHN A. BRASHEAR,
PITTSBURGH, PA.

DEAR MR. BRASHEAR,—

I wish to thank you very much for your thoughtfulness in sending me your very delightful sketch of a visit to Broughty Ferry, the home of Doctor Dick, the Christian Philosopher. I have read it over and over again with great interest. It carried me back fifty-seven years and made me think again of a truly great old man taking a kindly interest in a boy who was just beginning to open his eyes to the wonderful things all about and above him and how that contact with such a grand old character has been an uplift to me through all these years. I could not tell you what a pleasure your sketch has given me.

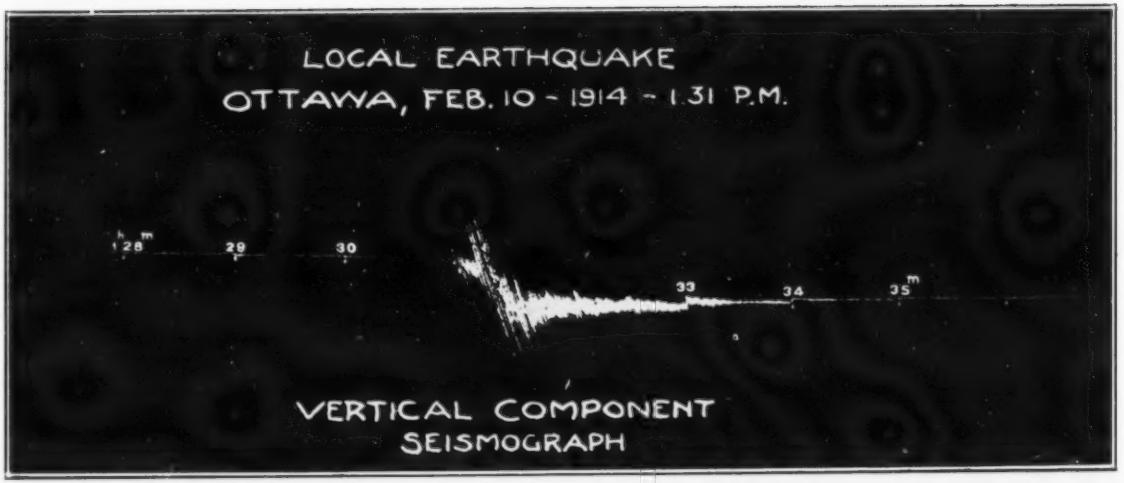
I trust to see you here next year and that I may have the chance to entertain you at San Mateo.

Very truly yours,

(Signed) G. W. DICKIE.

A LOCAL EARTHQUAKE

Herewith is reproduced an interesting seismogram obtained at the Ottawa Observatory by Dr. Klotz. The quake was felt in Eastern Ontario and in some of the Eastern States.



SEISMOGRAM OBTAINED BY DR. OTTO KLOTZ AT THE DOMINION ASTRONOMICAL OBSERVATORY, OTTAWA.

THE EFFICIENCY OF LIGHTNING RODS

There has been much questioning as to the real value of lightning rods. A considerable amount of scientific work, spread over many years, elucidated to a large degree the nature of the phenomenon ; but lightning is always terrifying and continually performs such unexpected "pranks," and furthermore the lightning rod fell into such disrepute through unscrupulous agents that many view it with suspicion.

However, anyone who reads *Bulletin* 220, published by the Ontario Department of Agriculture, will be convinced that properly installed lightning rods are a real protection. The author of the pamphlet is Professor W. H. Day, of the Ontario Agricultural College, and Vice-President of our Centre at Guelph.

In it he explains the scientific principles involved and in addition gives statistics of injury to buildings with and without protection. It is strange that the insurance companies in Ontario — and in most other provinces and states as well — had not carefully kept a list of buildings with rods and without them, but little of this sort appears to have been done until Professor Day took the matter up with them in 1912. The statistics already obtained certainly show the efficiency of the rods. In Ontario a building is about twenty times as likely to be struck without rods as with ; and this proportion is even greater in some other places.

C. A. C.